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Columbia Basin Irrigation Project.
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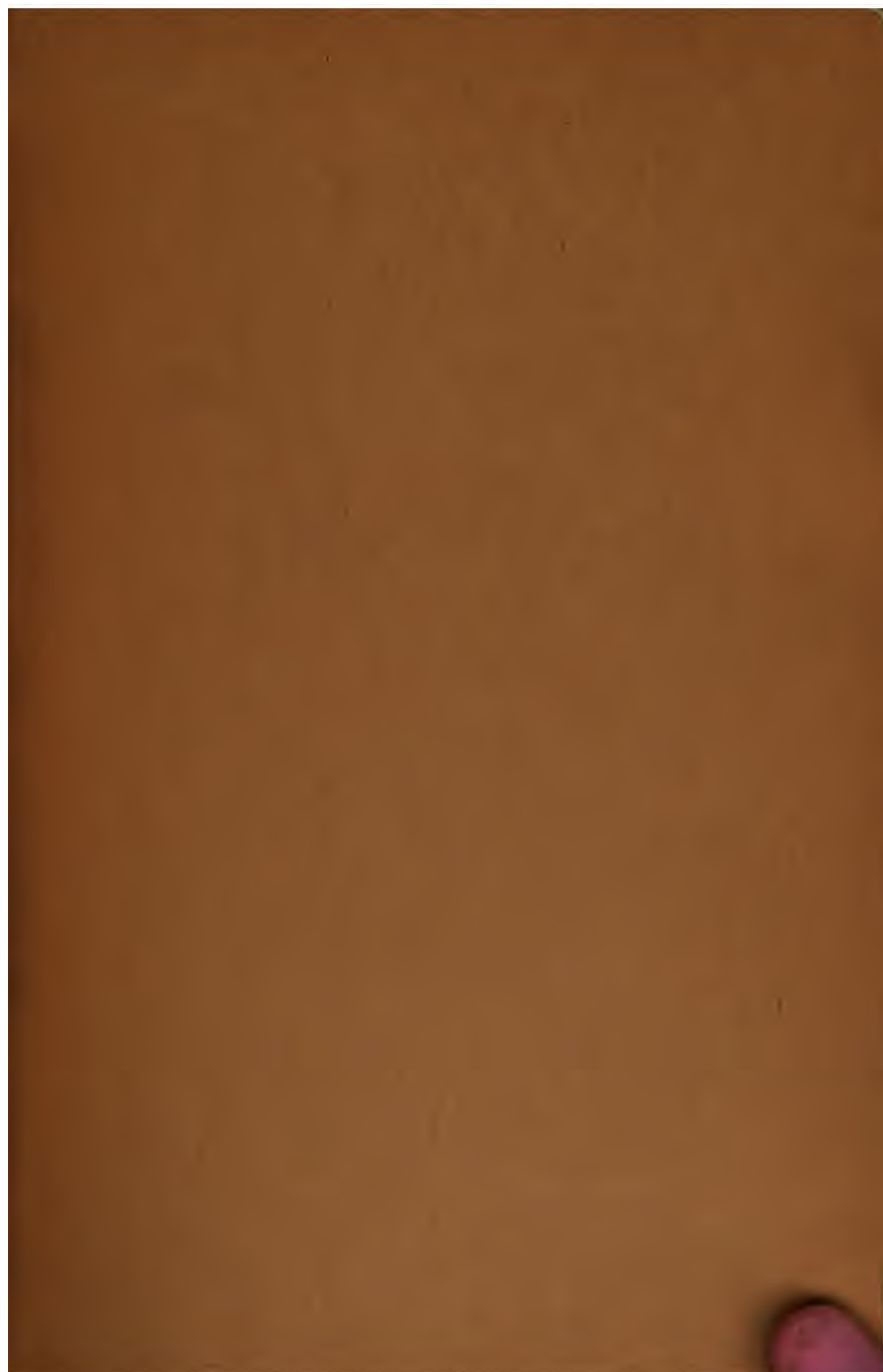


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Columbia Basin Project

A REPORT BY
GEORGE W. GOETHALS AND COMPANY, INC.



Department of Conservation and Development
State of Washington
Olympia
1921



Columbia Basin Project

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GEORGE W. GOETHALS AND COMPANY, INC.



Department of Conservation and Development
State of Washington
Olympia
1921

Columbia Basin Irrigation Project

State of Washington



A REPORT BY
GEORGE W. GOETHALS AND COMPANY, INC.
TO THE
Department of Conservation and Development
State of Washington

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DEPARTMENT OF CONSERVATION
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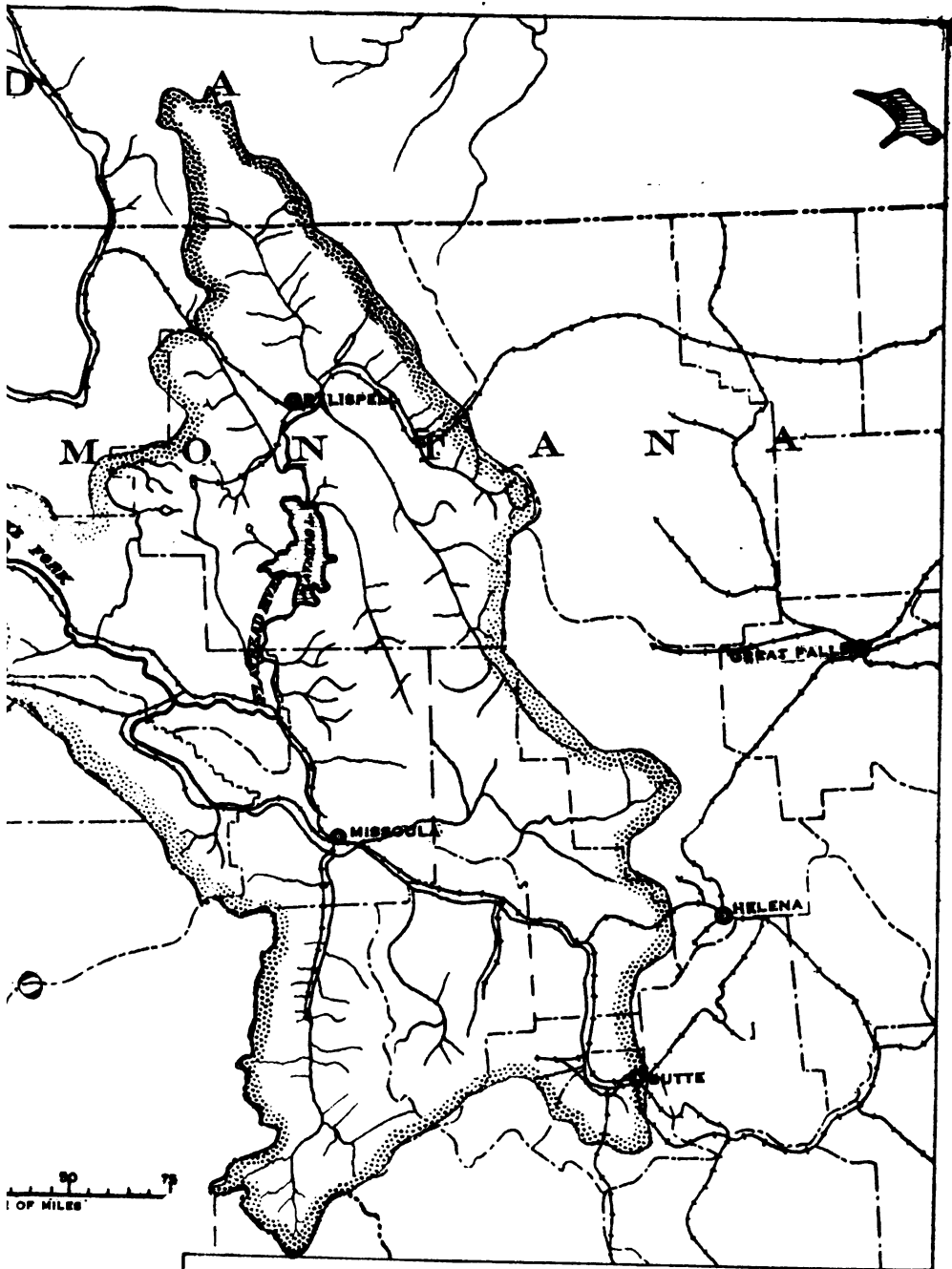


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Columbia
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COLUMBIA BASIN PROJECT
STATE OF WASHINGTON
1920



WATERSHED ABOVE ALBANY FALLS



PROJECT AREA

STATE OF WASHINGTON
LOUIS F. HART, GOVERNOR
DEPARTMENT OF CONSERVATION
AND DEVELOPMENT
D. A. SCOTT, DIRECTOR

DIVISION OF RECLAMATION
DIVISION OF FORESTRY
DIVISION OF WATER RESOURCES
DIVISION OF GEOLOGY
DIVISION OF COLUMBIA BASIN
SURVEY

OLYMPIA, WASHINGTON, April 7th, 1922.

Hon. D. A. Scott, Director,
Department of Conservation and Development,
Olympia, Washington.

DEAR SIR: At the close of the first year of work by the Columbia Basin Survey, as authorized by the Administrative Code of 1921, we submit the following statement of a portion of the work accomplished by that division of your department.

Early in the year, you appointed a board of engineers and geologists to "examine a portion of the Columbia River for the purpose of determining the location on the river at which borings should be made to ascertain the feasibility of a dam that would be required in connection with the alternate plan of pumpage development of the Columbia Basin Project."

Upon the recommendations of that board, the Grand Coulee site was diamond drilled and the depth and character of bed-rock ascertained; a topographic survey was made of the Foster Creek site and an estimate of the cost of electric development at that site, power transmission and electric pump installation at the Grand Coulee; and a detailed geological study was made by the Division of Geology of the tightness of the proposed Grand Coulee reservoir.

Cooperative studies were made with the Columbia River Board of the Federal Power Commission to determine the best use of a portion of the tributary streams, and a presentation was made to that board of the claims and rights of the State of Washington to control an adequate water supply for the Columbia Basin Project.

A large number of routine activities were carried on, among them being continuous discouragement of land speculation in the area proposed to be irrigated, assistance to smaller areas within the project in the study and procuring of local water supplies, revision of the plans and estimates for the larger project, and especially the compilation of data to further the progress of the McNary-Smith Federal Cooperative Reclamation bill now before Congress. The passage of that bill is expected to provide for the numerous smaller but equally meritorious projects and leave the way clear for presentation of the Columbia Basin Project for direct appropriation and construction by the national government.

Grateful acknowledgment is made to the numerous civic organizations and interested persons who have contributed very largely of time and money to the educational campaign which is being conducted throughout the nation for the benefit of western reclamation. Without such assistance it would not have been possible to create the present tremendous enthusiasm for the development of the Columbia Basin and other arid areas.

At the close of the year, Major-General George W. Goethals was engaged to review and report upon the feasibility of the construction problems of the project. His report is of such interest and value that we recommend its immediate publication.

The engineering and geological studies made earlier in the year are being placed in finished form and we suggest that these be included in the report of the current biennium.

Respectfully submitted,

DIVISION OF COLUMBIA BASIN SURVEY.

FRED A. ADAMS, *Supervisor.*

IVAN E. GOODNER, *Chief Engineer.*

GEORGE W. GOETHALS AND COMPANY, INC.
40 WALL STREET
NEW YORK

March 30th, 1922.

*The Honorable D. A. Scott, Director,
Department of Conservation and Development,
Olympia, Washington.*

DEAR SIR: We submit herewith report on the feasibility of the construction problems that will be encountered in irrigating the Columbia River Basin, aggregating approximately 2,000,000 acres of land lying between the Columbia and Snake Rivers, Washington, based upon personal inspection and investigation of all available data.

The lands under consideration and the methods by which irrigation is to be accomplished are described and set forth fully in a printed report entitled "The Columbia Basin Irrigation Project—A Report by Columbia Basin Survey Commission, State of Washington, 1920."

While three sources of water supply were considered by the Commission, only two methods were investigated and estimated for carrying water to the lands to be irrigated:

1. By gravity flow from the Pend Oreille River and its tributaries above Newport—called the Gravity Project;

2. By damming the Columbia River near the head of the Grand Coulee and pumping water to an artificial lake, whence it would flow by gravity to the areas under consideration—known as the Pumping Project.

GRAVITY PROJECT.

A summary of the data available is contained in the Commission's Report and in support is a voluminous mass of material collected prior to the issuance of the

report, as well as subsequent thereto, up to the time that we made the investigation. The supporting data include: Soil Classification; Water Requirements of the Land; Available Water Supply; Level Control; Studies and Designs of Engineering Structures, and Cost Estimates, as applicable to both the gravity and the pumping projects.

Soil Classifications. The work done in connection with this phase of the problem is indicative of the methods employed by the Commission on the entire project. Not content with the soil surveys covering part of the proposed district as contained in U. S. Government publications on soils, a force was organized to cruise the Columbia Basin, some 3,000,000 acres of land, considering the subject from the standpoint of irrigability. Soil experts and others competent through experience were employed and made the records now on file. These are complete and indicate for each section of every township not only the character of the soil but also its ownership.

Considering the character of soil and elevations of the various sections, it was determined that the aggregate amount of land susceptible to irrigation by the Gravity Project is 1,753,000 acres. An additional 91,000 acres may be irrigated by pumping less than 150 feet in height, and 317,000 acres by a higher lift; areas irrigable by pumping are not included in the estimates under the Gravity Project, neither are parts of the area suitable for grazing, for which water will be available, nor other portions which could be made into good farm lands were the stones and boulders removed.

Water Requirements. Investigation of the data by means of which Table No. 8 of the Commission's Report was arrived at, included search through all available records of important irrigation projects, and consideration of evaporation and seepage losses. As a result it was concluded that the requirements given by this table

are adequate for any character of crop the area under consideration can undertake. Should state or other control ever be such as to require a rotation of crops throughout the area, the supply here given would be more than sufficient.

No better criterion of Columbia Basin water requirements can be furnished than experience in the Yakima areas affords, particularly that on the Sunnyside Project. From this experience, records for which have become available since the Commission's Report was compiled, the following table has been set up for comparison with Table No. 8:

(1) Month	SUNNY- SIDE PROJECT	COLUMBIA BASIN EQUIVALENTS		
	(2) Acre-Feet	(3) Per Cent	(4) Gross Diversion Acre-Feet	(5) Flow in Second-Feet
April.....	0.274	9.0	500,600	9,421
May.....	0.539	18.5	1,152,200	18,738
June.....	0.541	18.5	1,152,200	18,738
July.....	0.538	18.5	1,152,200	18,738
August.....	0.550	17.5	1,089,900	17,725
September.....	0.380	11.0	685,100	11,514
October.....	0.226	7.0	426,000	7,090
Totals.....	3.098	100.0	6,228,200	.....
Average rainfall.....	.281	.....	.....	.....
	3.374			

In the foregoing table, column (2) has been compiled from official records as published for the Sunnyside Project and represents averages for the period 1912-1918, inclusive. Column (3) is set up from column (2). Columns (4) and (5) are computed by taking the same total gross diversion in acre feet for the Columbia Basin area as given in Table No. 8 of the Commission's Report and re-distributing on the basis of column (3) above. By comparing the last two columns with corresponding ones in Table No. 8, it will be noted:

(a) Over the irrigation period the total gross diversion is the same.

(b) The maximum gross monthly diversion is less than in Table No. 8, occurs earlier in the season, and is more uniformly distributed.

(c) The period of maximum requirement is advanced to a time of year when there is a greater natural run-off.

(d) The diversion required during September and October, when storage would be most severely taxed, is considerably less than shown in Table No. 8.

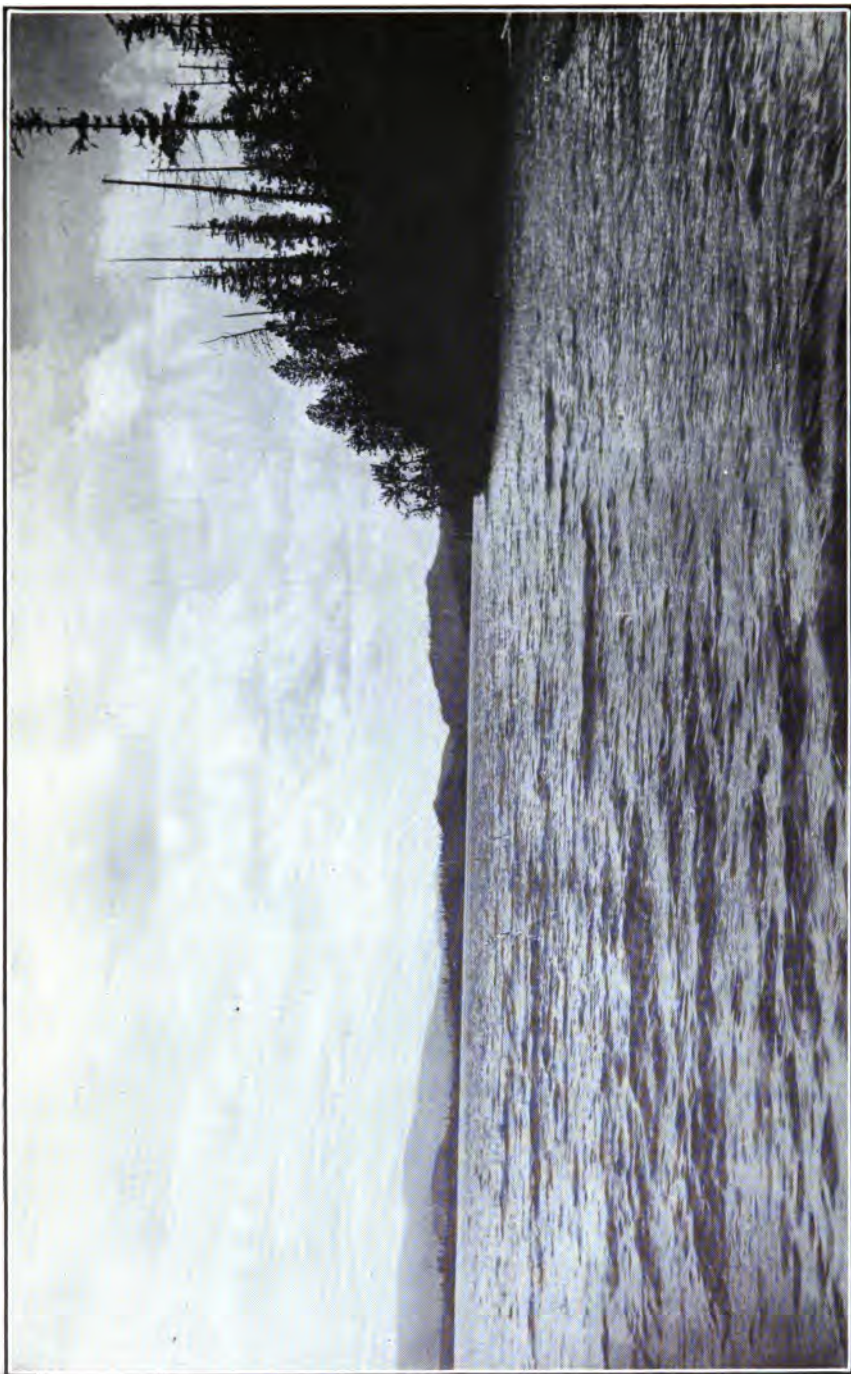
This comparison shows that the mass curve for water duty, as set up in the original studies of the Commission, may be flattened somewhat to conform to columns (4) and (5) above. This study is being carried on by Mr. Ivan E. Goodner, chief engineer of the project, and should further investigation prove such a change warranted, it will affect the size of the main supply canal and the mains below Hillcrest, with a consequent saving in the cost of the project, as presented herein.

Available Water Supply. A study and check were made of the computations necessary to verify Table No. 9 of the Commission's Report. Original sources of information regarding stream flow, as compiled in Government reports, were looked up, and an examination of the mass curves set up therefrom, together with the studies made therefrom, confirms the conclusions of the Commission concerning the supply from Pend Oreille Lake. The additional supply required is more than amply furnished by Flathead Lake.

Pend Oreille Lake is in Idaho, and Flathead Lake is in Montana; in other words, the sources of supply are in states other than that in which the area to be irrigated is located. We are assured, however, that this does not prevent the acquisition of the water from these lakes for the purpose intended.

The gauge station at Newport was reported by the Geological Survey for part of the period 1903-1919, and the Weather Bureau reported readings when the former discontinued. Under the latter, no gauge readings of the Pend Oreille River were made during the winter

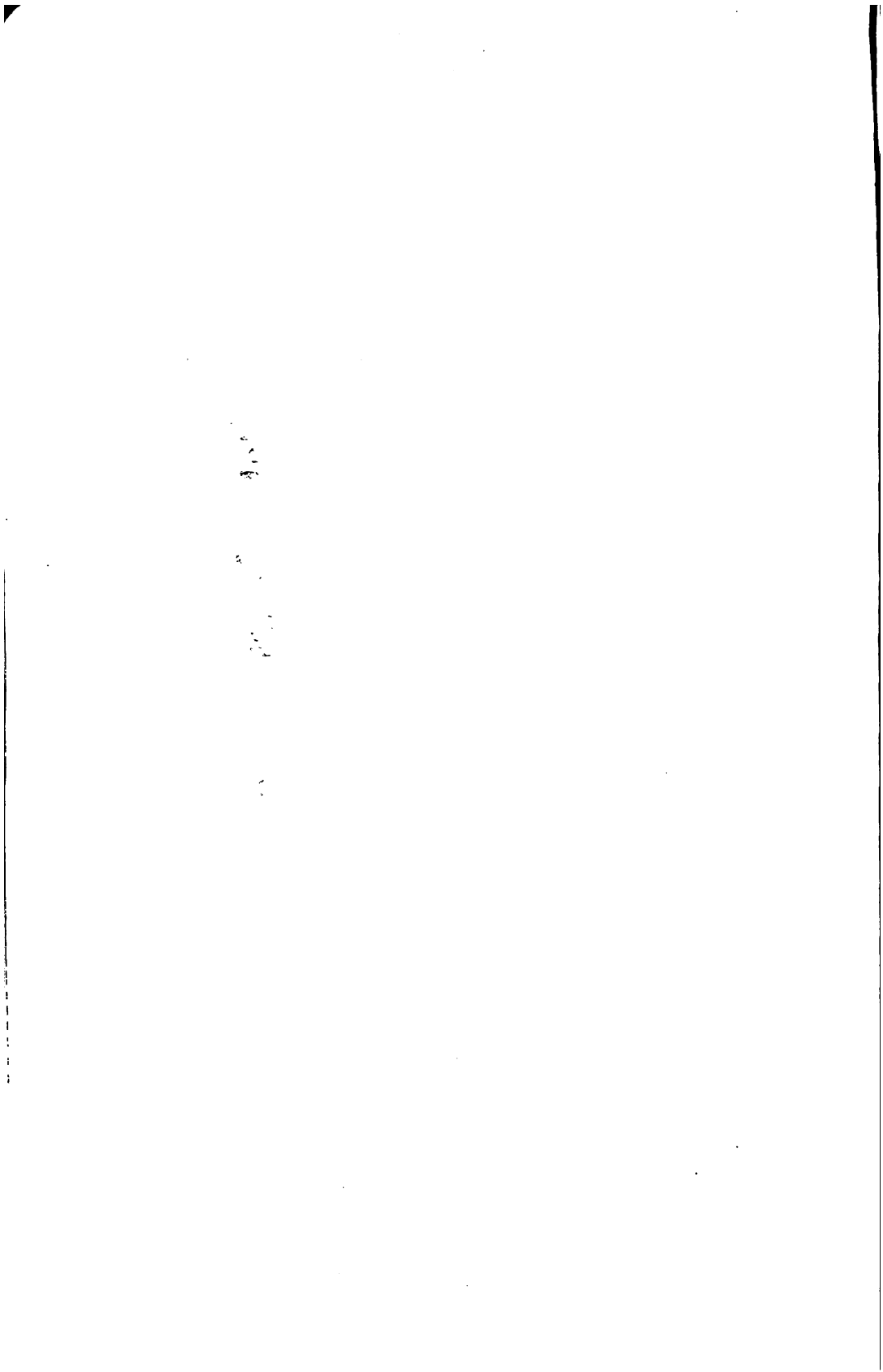




PEND OREILLE LAKE.
One of Primary Storage Reservoirs.



ALBANY FALLS, IDAHO.
Place of Diversion of Main Canal.



months, but the readings at Metaline Falls below, under the supervision of the Geological Survey, are complete for the entire year by months. The Commission's assumption that the flow at Newport during winter months may be taken at not less than 95% of the flow at Metaline Falls, is conservative and errs on the side of safety as regards volume of water available at Newport for irrigation. We also find that this assumption was checked independently by computing the sum of the stream flows above Newport and comparing the result with the gauged flow at Metaline Falls. The difference of less than 5% was found to be closely checked by what information was available regarding the flow of Sullivan Creek, the only stream worth consideration entering the Pend Oreille River between Newport and Metaline Falls, and which has a very small contributory drainage area.

There is no question of the adequacy of the water supply with storage provided in Pend Oreille and Flat-head Lakes to the elevations noted in the Commission's Report.

Level Control. The data on hand in regard to the methods of establishing elevations were examined down to field notes. This important work was carried out satisfactorily using wye levels. The lines as run were tied in with Geological Survey bench marks and the discrepancies were found to be well within the customary allowable errors for the distances. Wherever larger variations were found care was taken to check them up and make the necessary corrections. In cases where the error was with the bench marks of Geological Survey, the questions were taken up with the officials of the survey and the matters in dispute settled. Level lines were also tied in with Coast and Geodetic Survey bench marks as well as with those of the various transcontinental railroads.

Structures. The structures proposed for the control and distribution of the water include concrete dams at Pend Oreille and Flathead Lakes with regulating gates designed so that the maximum flood at each locality would be passed freely without injury to property. The supply canals are all computed and designed accordingly with concrete linings which permit of steeper grades and therefore higher velocities, at the same time reducing losses. A large amount of tunneling is made necessary by the topography of the land and in some instances tunnels were selected in lieu of open canals because careful study showed the economy of the former. At some of the streams, canyons and coulees, inverted steel siphons proved to be the most feasible and economical method of crossing, but because of high pressures and the limits of present day practice, diameters were limited, necessitating the use of several instead of one or two siphons or pipes. To carry the supply canal across the Spokane River involved the study of various methods and designs before the aqueduct was decided upon as the best and most economical solution.

The various studies and designs are of record and indicate that each problem that the project presented was carefully studied and that solution adopted which offered the greatest reliability and safety. The Commission and all connected with it are to be commended for supporting its project with such detailed data and design, some of it not usually attempted until detailed design is prepared for the construction stage of work.

While the work already done enables close estimates of cost to be made, it is recognized by the Commission and its engineers that further examinations are necessary from which may result a reduction in the final cost of the work. Such investigations contemplate borings to determine the character of material that may be encountered during tunnel excavation; further exam-

ination to develop foundations of some of the rock-fill dams; more study relative to the location of the main supply canal, together with curves that should be adopted with special reference to their effect in creating waves or jumps, and to siphon designs. As is usual in projects of this character and size, such additional detailed studies are made when the project has been financed. Provision for such studies and examination is made in the estimates by an allowance for engineering and proceeded with as the construction progresses.

All the structures proposed by the Commission are feasible and practicable and offer no engineering difficulties.

Cost Estimates. An exhaustive examination was made of all the data available and on which the estimates presented in the Commission's Report are based. The estimates were compiled prior to the publication of the Commission's Report, at a time when costs of material and labor were at the peak. Every particular part of the project was separately estimated with consideration given to locality, the proximity of suitable materials, the construction equipment that would be used, cost of transportation, labor and all other items entering the cost.

Since the compilation, both materials and labor have been reduced and the figures given herein are the result of the lower prices as affecting the estimates. In preparing our costs the structures and quantities have been taken as determined and computed by the Commission and the revision is due to the application of different unit costs. The principal comments and changes are as follows:

(a) Costs adopted by the Commission for ordinary excavation of the three customary classes have not been changed. This is due to the fact that on a project of this magnitude labor in excavation will play a comparatively small part, inasmuch as the use of the most up-to-date excavating machinery will everywhere be justified. The costs adopted

by the Commission are supported by those used on work of a similar character.

(b) Unit costs for tunnel excavation have been reduced to a basis of \$5.19 per cubic yard. This reduction is based on estimates which we prepared in September of 1921 for similar work on the Skagit River Power Development project, and also by a later estimate for similar work nearer Spokane to which we had access. The proposed reduction is supported by recent inquiry from the consulting engineer originally called in to prepare the tunnel estimates. The unit costs for each particular tunnel have been adjusted on the same proportionate basis as the costs used by the Commission varied from the average cost in its report. This variation is due to special considerations at the different tunnels, such as length of railroad outside, length of haul, cost of construction camps, accessibility to existing railroads and highways, and relative difficulty in getting construction plant to the sites.

(c) A reduction to \$10.00 per cubic yard has been made in the cost of the concrete lining for tunnels, due to the reduced price of concrete aggregate and cement; likewise in the use of pneumatic equipment for placing the concrete. No reduction has been made in the thickness of the lining nor the quantities.

(d) For similar reasons concrete for canal lining has been reduced to \$9.60 per cubic yard. Following the method adopted by the Commission, reinforcing steel is carried as a separate item. The thickness of the lining seems excessive and the concrete richer than necessary, but the changes have not been made in these nor in the quantities.

(e) Reinforcing steel has been reduced to 4c per pound to conform to reduction in prices of material.

(f) Plain concrete in comparatively small quantities has been reduced to \$10.50 per cubic yard.

(g) Light reinforced concrete has been reduced to \$12.00 per cubic yard and heavy reinforced concrete to \$20.00 per cubic yard.

(h) Structural steel in gates has been reduced to 9c per pound and structural steel required for road crossings to 7c per pound.

(i) The item for riprap in rockfill dams has been reduced to \$1.50 per cubic yard. With such a dam properly constructed, with suitable material utilized on the face, hand placing of riprap is not necessary; so the item for preparation for facing, which appears under most of the estimates for rockfill dams, has been eliminated.

(j) Steel sheet piling has been reduced to 4c per pound.

(k) Siphon steel has been reduced to \$0.056 per pound. This reduction is due principally to drop in material prices. The other figures for the cost of this steel, as shown on page 105 of the Commission's Report, have been reduced slightly, with the exception of freight, which has been increased to \$1.67 per cwt. to conform to present rates. At the time this material is ordered, a still further reduction can unquestionably be made by shipping the steel from Baltimore to Seattle

by sea. The rail rate has been taken in order to afford a consistent comparison with the figures set up originally in the Commission's Report.

(l) Like reductions have been made as applying to various comparatively small quantities of work under the miscellaneous items appearing in the recapitulation tables in Appendix G, Commission's Report.

(m) Overflow rights have not been changed, although late information indicates that in some places the land may be purchased at figures less than were originally allowed.

In preparing the estimates for each particular structure an allowance averaging 2% was added for engineering. In view of the data available this is considered ample, but the total item for engineering as it appears in the Commission's data is adopted without change.

The items for contingencies included in the estimates of the Commission and determined for each part of the work seemed sufficient and were adopted in the estimates presented herein at the same amount as given by the Commission. In the original estimates these items vary from 5% to 20%, depending upon the character of the work and surrounding conditions. These were regarded as ample in view of the fact that the following allowances were made. In tunnel work an increase of 15% was added for overbreak, while the lining was increased by 7%. In the same way computed canal excavations were increased by 15% throughout, while in some portions of the distribution canals through rough country the computed quantities to be excavated were increased by 50%. In the linings for the canals the computed quantities for concrete were increased by 7%.

For the purposes of this report no attempt has been made to set up corrected tables of estimates corresponding to each of those in Appendix C of the Commission's Report. For comparison it has been deemed sufficient to set up the Recapitulation Tables Nos. 41 to 45, inclusive (Appendix G, Commission's Report), corrected to

the revised unit costs aforementioned. These corrected tables are attached hereto as Exhibit 1.

The revised estimated cost of the Gravity Project is \$254,170,351, or \$144.99 per acre. This includes the portion of the area in Walla Walla County. Should the latter be developed independently, as now appears possible, a saving would be made, with a small reduction in cost per acre, on account of the elimination of the Snake River siphon, one of the most expensive individual structures in the project.

Secondary Storage. Secondary storage was considered by the Commission. Its value in connection with the supply canals lies in the capacity provided for holding in each lake water which would otherwise be wasted from the main canals after a shut-down. Table No. 37 was checked and found to be correct. Further study of secondary storage on the project may result in reducing the cost of the canals and in furnishing power for pumping water to areas not reached by gravity and therefore not included in the irrigable area of the project.

Drainage and Wasteways. In some of the existing irrigation projects trouble has resulted from waterlogged lands, due to the failure to provide proper drainage. In the area under consideration are found numerous lines of surface drains, draws and coulees, which would be running streams were the rainfall sufficient. These were caused by the run-off from the melting snows and ice of the Glacial Period. An examination of the map accompanying the Commission's Report, opposite page 116, shows the relation of these natural drains to the proposed laterals of the project, so the conclusion that drainage will be largely cared for is correct. It would be difficult to lay out a proper system of drainage in a project of this magnitude, but as so much of it will be taken care of naturally the small amount that experience

may ultimately show to be necessary can be added without much expense.

The Commission, with its usual thoroughness, examined into the question of wasteways and made the necessary provisions to care for diverting or discharging the water from the supply and main canals wherever the necessity therefor arises.

Time for Completion. In the data worked up by the Commission is a carefully prepared schedule for the tunnel work, which is the determining factor in fixing the time within which the entire Gravity Project can be completed. This taken in connection with the other structures that must be built has led us to the conclusion that the project in its entirety can be completed within six years, if money is made available as the progress of the work warrants.

Annual Operating Cost. In order to arrive at the cost of operation and maintenance, a tentative schedule has been set up which is shown in detail in Exhibit 2. The total amount is estimated at \$841,450, or \$0.48 per acre.

Partial Development of Gravity Project. The project as outlined contemplates the expenditure of the larger portion of the estimated amount required for the project before water can be placed on any of the land. With the object of securing a quicker return and to reduce the amount of money required it has been suggested that the project can be partially developed or the work can be cheapened by omitting linings, by means of wood pipe, or temporary construction, which can be made permanent later on.

The partial development of the project was given some consideration by the Commission and this has been reviewed and an independent estimate worked up. It is assumed that the entire area would eventually be

irrigated so that open portions of mains and laterals would be built to full section at once; hence the ultimate cost to the farmer, who must pay the bill, will be less than if such portions be attempted piecemeal. To leave the main canals unlined will increase friction, maintenance and ultimate cost. It is true that only one tunnel bore, when twin tunnels are provided, need be constructed at first, but these should be lined at once to reduce friction, maintenance and ultimate cost. Inverted siphons at the various crossings could be reduced in number of ducts to correspond to a capacity required to handle the flow of one tunnel bore along the main supply canal. Siphon supports would be reduced wherever possible. The dam at Flathead Lake would not be necessary. Below Hillcrest an area has been assumed as the one to be served by this initial partial development. It represents approximately 880,000 acres. In laying out this area consideration was given to accessibility, character of soil, and the relative costs of different sections of the various mains below Hillcrest.

Exhibit 3 gives a recapitulation of the estimated cost of this partial development. The form follows that given in Exhibit 1, so that ready comparison may be made. Items are given in numerical sequence, omissions indicating those items in Exhibit 1 not needed in the partial development scheme.

From this it will be seen that to bring 880,000 acres under irrigation—about 50% of the entire project—it will cost \$149,642,653, or \$170.04 per acre. It will be cheaper in the end so to lay out the construction program as to bring about simultaneous completion of the entire project, including 100 second feet capacity laterals, rather than to develop the Basin area partially first and to complete it subsequently.

Substitution of wood pipes or any temporary construction for the canals would reduce the initial cost

but they would ultimately have to be replaced at increased cost, which must in any event be borne by the farmer, and it seems ill-advised in a project of this magnitude to resort to anything except the completed project, as outlined in the report.

PUMPING PROJECT.

This project contemplates building a dam across the Columbia River near the head of the Grand Coulee and using the energy thus stored to operate pumps for raising the water to an artificial lake created in the Grand Coulee, whence water flows by gravity to the Basin area.

Since the Commission's Report was issued, borings were made to disclose the position of rock and fourteen holes were driven. Rock is found 40 feet below the river at the nearest point and is practically horizontal, with the exception of a depression in which the rock falls off to a depth of 110 feet. The character of the rock is not uniform, as disclosed by the cores, but the samples are such as to secure a good foundation for the structures.

Mr. W. T. Batcheller, consulting engineer, was retained by your Department in connection with the design and estimates of the electrical and mechanical equipment required for the project. His report was available for consideration and covers not only the work for which he was retained, but a design for the dam, the diversion channel, and a review of the entire project. In addition to this, the data prepared by the Commission were also available.

The natural flow of the Columbia River renders a sufficient amount of water available for irrigation purposes. As the Batcheller report covers a discussion of water power development for commercial uses, and as for the combined purposes the Columbia River supply would not be adequate for the commercial power that he con-

templates, additional storage is provided in Flathead and Pend Oreille Lakes. These have not been considered by us in arriving at the estimates for the Pumping Project to be used in comparison with the estimates for the Gravity Project.

Two methods of pumping operation were considered and several heights of dam have been studied. In one, the pumps themselves are direct connected to the turbines and the power principle is entirely mechanical in nature. In the other, the pumps are operated by electricity furnished from generators direct connected to the turbines and the pumping station is constructed as a separate unit above the dam in order to reduce the working head.

For the purposes of the comparisons made by this report, only three of the dams studied have been considered. Dam No. 1 provides an effective head of 123 feet and contemplates the use of hydro-electric units. This dam, without other storage delivered at the dam from above in amounts that can be accurately calculated and depended upon, would give a shortage of power, even for pumping purposes, for ten of the months of the nine-year record of river flow available for our study. In other respects, this dam comes so near filling the requirements of irrigation needs alone, that estimates therefor have been followed through for sake of comparison.

Dam No. 2 provides an effective head of 175 feet, which is the minimum head capable of operating the direct connected two-stage pumping units contemplated over the irrigation season.

Dam No. 3 provides an effective head of 211 feet, which comprises a hydro-electric installation. No dam of greater height has been considered, as such would back water above the lower pool at Kettle Falls, aside from causing more extensive overflow damages.

The dams discussed lie within feasible limits of consideration. Dams of less than 211 feet effective head would scale in cost within the limits set up for the three types under comment. The comparison furnished by these three is therefore regarded as sufficiently comprehensive for present purposes.

Cost Estimates. These are presented under two general headings: One for the dams, and the other for the gravity portion of the Pumping Project. The former estimate comprises not only the dam but all structures to the beginning of the gravity supply canal, including power house, pumping station, machinery, and pipe lines.

The following comments on the estimates for the dam are given:

(a) A theoretical profile for the dam was adopted for purposes of preliminary estimate to conform to standard types. Detail design might modify this section somewhat.

(b) The capacity of the river diversion has been figured at 100,000 second feet. A diversion carrying 65,000 second feet, as was suggested, was not adopted, for this capacity would not afford a sufficiently long working season. The work under the water conditions existing in the Columbia River is difficult and as long a working season as possible must be secured for the foundation work in the river section.

(c) In computing excavation, 10 feet clearance on either side of the base of the dam has been allowed, with side slopes of 2:1. On account of the material indicated by the borings, the working room must be ample to provide against any tendency on the part of the clay stratum to squeeze out under its superimposed load. To take care of difficulties during excavation, 50% of the quantity involved has been figured at \$1.50 per cubic yard.

(d) The excavation is figured once. How much extra work must be done in removing material brought in during floods is unknown.

(e) Concrete has been figured at \$10.50 per cubic yard, the same as in the Gravity Project. Rock for concrete will have to be quarried at the site and if Mr. Batcheller's verbal report is correct, this rock will have to be screened. He also questions whether suitable sand deposits can be secured in the neighborhood on account of the excessive fineness of the existing beds. Whether the granite is suitable to furnish sand is also unknown; so that the figure of \$10.50 here adopted may be exceeded.

(f) A down-stream apron 300 feet in length has been taken for these estimates because it is so indicated on Mr. Batcheller's drawings.

From experience elsewhere we do not endorse this length as sufficient in view of the fact that during extreme floods there may be a depth of 30 feet on the spillway.

(g) Excavation for power house has been figured to rock. While clay at the site might afford suitable foundation for almost any other type of building, it is not regarded suitable for the enormous machinery loads involved and the heavy vibrations that operation will cause. No experiments with stability can be made here.

(h) Unit costs for reinforcing and structural steel have been taken to correspond with those adopted in Gravity Project estimates. Same applies to light and heavy reinforced concrete in small quantities in power house and pumping station and elsewhere.

(i) Costs of machinery and miscellaneous incidentals have been adopted from the data furnished by Mr. Batcheller.

(j) The Treaty of 1846 between the United States and Great Britain requires that the Columbia River between the international boundary and the ocean be kept open to navigation. If the treaty rights are to be preserved—and there is little likelihood that Great Britain will give up what may in years to come prove a valuable transportation route—locks would have to be provided at the Columbia River dam. The estimates must, therefore, be read remembering that the cost of locks has not been included.

(k) Estimates for power plant include that required for irrigation purposes only.

Since the Commission's Report was written, geological investigation indicates that the location originally intended for the Coulee City dam is not a good one. A stratum of basalt takes a sudden dip just north of Coulee City and a geologist's report indicates the presence of faults and crevices at or slightly upstream from the originally proposed site. Under these circumstances, the Commission already contemplated moving the Coulee City dam about two miles northward. This makes a longer dam necessary and accounts for the large difference in estimated cost here given. It also increases the length of the main supply canal between the Columbia River and Bacon Lake, which has also been taken into account.

The items for engineering and contingencies are made at approximately 2 per cent and 16 per cent respectively. The former will enable further investigations to be made

of the foundations, suitable quarry sites, the railroad line that must be built, details of the construction plants required, and the effect that the overflow will have on the apron and the very structure of the dam itself. The latter is conservative when the difficulties encountered in the construction of dams in rivers of magnitude less than that of the Columbia are considered. It is much lower than we have used in projects of less magnitude. At the site of the dam the river flows through a narrow gorge, increasing the difficulties of construction, in this respect different from large rivers where dams have been constructed. The variations in river flow during floods are greater than in other streams successfully dammed, and the quantity of water to be handled is also much greater.

The pumping plant for the 211-foot dam is unprecedented, consisting of 17 units, each with a capacity of 1,000 second feet, against a head of 407 feet.

Exhibit 4 gives estimates of the three types of dams. They are stated in some detail because there are no corresponding data in the Commission's Report.

The area to which water can be delivered by the Pumping Project is 1,403,000 acres. Mr. Batcheller proposes to install another pumping system at Bacon Lake by which 4,000 second feet will be lifted 200 feet, thereby extending the area to be irrigated by an additional amount of 454,000 acres or a total of 1,857,000 acres. Unfortunately, most of this additional acreage is not classed as irrigable lands and the former chief engineer of the Commission advises us that because of differences of level, water will not flow to this acreage through the canal proposed.

Exhibit 5 is made to correspond to the recapitulation tables Nos. 55 to 58, inclusive, as given in Appendix H, Commission's Report. The total estimated cost of the Pumping Project with Dam No. 1 is \$223,096,943, or

\$159.01 per acre; with Dam No. 2, \$228,990,358, or \$163.21 per acre; with Dam No. 3, \$241,487,258, or \$172.12 per acre.

Given the time and the money, the dam can be built, and the Allis-Chalmers Company has furnished a general design of pumps, which they believe will do the work. No such pumps have as yet been built.

Annual Operating Costs. Exhibit 6 gives a tentative estimated operating schedule, classified under the three types of dam. Only those power units serving the irrigation project are included. The organization for a power plant of this magnitude is necessarily large and economy cannot be sought in assigning too many machines to individual supervision. The wages of the extra men will be more than repaid when measured against machinery damage due to inadequate care. Salaries outlined are high but the work is important and isolated and more than ordinary wages must be offered to secure permanent services of the proper type of men, with inducement to hold them during the winter season when ordinary repairs and overhauling would have to be made. The operating organization beyond the beginning of the canal is similar to that given for the Gravity Project, and deserves no special comment.

The estimated annual operating cost with Dam No. 1, is \$2,604, 275, or \$1.86 per acre; with Dam No. 2, \$2,124,095, or \$1.51 per acre; with Dam No. 3, \$2,192,605, or \$1.56 per acre.

COMPARISON OF PROJECTS.

The following table has been set up in order to show a ready comparison between the salient elements of cost of the projects discussed:

COMPARATIVE TABLE OF TOTAL AND UNIT COSTS.

ITEMS	GRAVITY PROJECT		PUMPING PROJECT		
	Full Development	Partial Development	With Dam No. 1	With Dam No. 2	With Dam No. 3
Total Estimated Cost..	\$254,170,851	\$149,642,853	\$228,096,943	\$229,990,358	\$241,487,358
Acres Irrigated.....	1,753,000	890,000	1,408,000	1,408,000	1,408,000
Construction cost per acre.....	\$144.99	\$170.04	\$169.01	\$168.21	\$172.12
Estimated annual operating cost.....	\$941,450	\$520,500	\$2,610,275	\$2,124,095	\$2,192,605
Annual operating cost per acre.....	\$0.48	\$0.59	\$1.86	\$1.51	\$1.56

CONCLUSIONS AND RECOMMENDATIONS.

From the study made, the adoption of the Gravity Project is recommended for the following reasons:

- (a) It develops the largest acreage.
- (b) The construction cost per acre will be lower.
- (c) The annual operating cost will be much lower.
- (d) The reliability and simplicity of a direct gravity flow of water are immeasurably superior to the complexity of operating a power and pumping plant with a large number of turbines and pumps which would be stressed higher than any existing equipment of equal capacity.
- (e) No treaty stipulations have to be solved, enabling construction work to start immediately funds become available.

POWER POSSIBILITIES.

Mr. Batcheller stresses the commercial value of the power that will result from the Pumping Project, which he proposes to sell to existing commercial companies, thereby reducing the acre cost for irrigation. This is a question for the future and cannot be considered in an irrigation project for today, as there is no prospective market at present and inquiries of existing companies give no hope of disposing of such power.

The Gravity Project also offers power possibilities which are set forth in the Commission's Report but are

not considered nor reflected in any way as affecting the acre cost for irrigation.

There is no question that all power possibilities should be reserved for use of the irrigated lands, either for extending the area or for commercial purposes, the money received in the latter case to apply to the benefit of the whole area.

As between developing power in large quantity at a time when there seems little likelihood of its being absorbed, and the gradual development of power to meet demands as they arise, the latter is the more rational policy to adopt. The Gravity Project, so far as power possibilities are concerned, is, therefore, the better.

FEASIBILITY ON THE BASIS OF COST.

The Gravity Project is feasible from a construction standpoint, since the various structures which go to make up the completed whole offer no engineering difficulties and all have been successfully accomplished elsewhere.

Objection has been raised to the project because of its size, but this is not sound, for in any project the details are the vexing questions, not the magnitude; with the former satisfactorily solved, the completed whole follows as a sequence, irrespective of size. Larger projects have been undertaken in Egypt and India, and the Colorado River development we believe will be larger.

Feasibility of construction does not in itself offer justification for undertaking this or any other project, for in addition there must be considered the question: Will it pay if completed?

In arriving at a conclusion on this phase of the problem, the character of the land, climate, crops and markets, transportation facilities, the possibilities of settlement, the cost of land and its preparation for water must be considered.



UNIRRIGATED COLUMBIA BASIN.



IRRIGATED YAKIMA VALLEY.

Character of the Land. Yakima stands out prominently as one of the most successful irrigation projects undertaken by the Government and the land has returned handsome profits to the farmer and added materially to the national wealth. The same remarks are applicable to Wenatchee, an irrigation project undertaken by private interests. The Columbia River Basin is adjacent to these and geologically it is part of the same formation as Yakima and Wenatchee. According to geologists, the lands embraced within the Columbia River Basin were part of a great lake bottom over which were deposited the detritus from the basaltic formations of its sides and bottom. This deposit was later augmented when the water broke through the Cascade Range to the Pacific and the lake receded. The soil is deep, rich, and abundant, and will be as productive when brought under water as are Yakima and Wenatchee districts.

Climate. The Columbia Basin has a short mild winter and a long growing season with much sunshine. The area is deficient in rainfall, because of which it has many desert characteristics and not because of soil or surface conditions. When small areas have had this deficiency supplied through irrigation, the crops have been abundant. The soil and climate of the Columbia Basin are so similar to those of the Yakima Valley that, given the necessary water, the productivity of the former will be as great. While there is a similarity of temperature in Yakima and Columbia Basin regions, the latter has the advantage of a two weeks' longer season.

*Crops and Markets.** "The logical agricultural development of this great area will yield products for which there will always be a profitable market. Wheat, now the predominating crop, can be augmented many times without producing noticeable effect on the world's market.

* From Commission's Report, page 16, (4).

"Alfalfa, clovers, grasses, potatoes, corn, sugar beets, wheat, oats, barley, seeds and fruits are all well adapted to the climate and soil of this region and would produce heavy yields of high quality. Livestock products, primarily dairy and pork, would logically accompany this kind of crops and would make a well balanced intensive type of farming with staple products, a very important consideration in developing a permanent system of agriculture.

"Fruits, berries, honey, and vegetables produced on the project can be marketed through growers' associations similar to those of Yakima, Wenatchee, Spokane and other irrigated districts of the Northwest. Sales may therefore be made in accordance with established methods and the entire output handled as a unit, thus eliminating the uncertainties of marketing. The large cooperative organizations in the fruit districts of the South and West have proved that successful marketing may be accomplished on any desired scale. They have gone further and shown how to create a new demand where the old was not sufficient to absorb an excessive output.

"Dairying should be an important industry on the Columbia Basin Project. It is likely that a large percentage of this area will be seeded to grasses. An abundance of forage and grains and the mild climate are conducive to the promotion of a great dairy industry."

Transportation Facilities. The transportation facilities—rail, highway and water—are excellent. The Columbia Basin is traversed by four transcontinental railroads with branches leading in all directions. State and county highways provide adequate service from the farms to railroad connections. Water transportation is provided by the Columbia and Snake Rivers. These various facilities afford direct means for transporting

the products from the fields not only to nearby cities but to all the markets of the world.

Possibilities of Settlement. The Secretary of Agriculture, predicting a population of 150,000,000 by 1950, stated that the acreage of improved farm land per capita has steadily decreased since 1890. To maintain the present per capita acreage in 1950 will require additions of approximately 8,000,000 acres of improved lands annually. With the productivity of Yakima so well known, similar lands will not lack settlers as soon as it is under water, provided the cost is not prohibitive. Increase in crops means more business for the railroads, which will assist in securing settlement. Various authoritative sources have stated that there will be no difficulty in placing suitable settlers upon the area as rapidly as water can be made available for each tract. No apprehension need be felt concerning the settlement of the lands.

Cost of Land and Its Preparation for Water. The Commission gave the question of land cost careful study and consideration and has arrived at certain values which we are not in a position to criticize. The probabilities of speculative values were discussed and the opinion exists that the state will undoubtedly be able to take measures to prevent exploitation of the farmer.

In arriving at the cost of placing water on the land, the Commission had the advice of agriculturists and engineers of many years' experience in the Yakima Valley, and fixed the price at \$15.00 per acre.

The two items, together with the revised estimates for the project recommended, would make the cost of land ready to start planting from \$165.00 to \$195.00 per acre, depending upon the value of unirrigated land fixed by the Commission.

Whether the undertaking is warranted at these figures has been carefully considered. A comparison with

existing projects cannot alone determine the question, for most of these were constructed at low prices for labor and material. In addition, the present project carries the water down to include laterals with flow of less than 100 second feet; in short, to the fence of the farm; furthermore, the construction is permanent, which is not always the case in other projects. Inquiries of those having experience, whose opinions bear weight, and who are wholly disinterested in the Columbia River Basin project—combined with the transportation facilities and the productivity of the land, exemplified by Yakima and Wenatchee—have led to the conclusion that the project is justified if irrigated land values range from \$200.00 to \$275.00, and that the farmer will receive a profitable return on his investment, from even the higher valuation.

In our judgment the project is feasible, not alone from the standpoint of construction, but from that of economics as well.

The existing policy of the U. S. Government, so far as concerns reclamation projects already undertaken, is for the farmer or land owner to reimburse the Government for the cost of the works, no interest being charged for the use of the money. Also, the farmer is allowed ample time to make good on his land before payments towards capital are exacted. While the policy is a liberal one, the irrigated areas have increased national wealth and returns are made to the National Treasury in other ways than through the payment of interest charges, so that indirectly these are more than fully met.

The project under consideration cannot be financed in the ordinary way through bankers, who loan on existing securities and not upon those to be created. The state is not financially in a position to undertake it, so there remains only the Federal Government. The U. S. Reclamation Service, Department of the Interior, has a revolving fund—outside of appropriations for specific

projects—for use in reclaiming arid lands in the West, but this is not large enough to undertake a project of this size. Excellent results have been accomplished by this fund and it should be left for the use for which it was intended.

The Columbia Basin Project is as much a national one as were the Panama Canal and the Alaskan Railways and will, if completed, add much more to the national wealth than either of the others mentioned. The work should be provided for and carried out as were these other two national projects—by direct appropriations.

Though located in the State of Washington, the benefits from the project will not be confined thereto but will extend to all parts of the United States. Through it pace will be kept with the ever increasing demand for foodstuffs of all kinds which will furnish increased business for all transportation facilities. It was stated, concerning Wenatchee Valley, that for every carload of fruit shipped out of the irrigated district a carload of manufactured goods is shipped in. The same will be true of the Columbia River Basin. Towns will spring up throughout the area. The demand for manufactured products—necessities and luxuries—will necessitate an increase of production in the various industrial sections of the country. It required vision to conceive the project; far less imagination is needed to picture the benefits that will accrue to the entire country through its realization.

The Federal Government is the only agency that can financially carry the project to completion, the only one that can absorb the interest charges and give to the farmer the time necessary to repay the capital—the cost of construction. That the United States will be fully repaid indirectly for the interest charges, cannot be questioned by anyone who gives the matter any thought or who will consider the returns already accrued from the

Yakima Valley Project. The Columbia River Basin is merely an enlarged Yakima Valley.

ACKNOWLEDGMENT.

The Department of Conservation and Development took over the work of the Columbia Basin Survey Commission. To the Director, Honorable D. A. Scott, who arranged for the field inspection and the investigation of available data; to Mr. Ivan E. Goodner, Chief Engineer of the Department, who presented and later explained the data; to the members of the former Commissions and its Chief Engineer, Mr. Arthur J. Turner; to Mr. Marvin Chase, State Hydraulic Engineer; to Mr. Lars Langloe, Field Engineer; to Mr. J. C. Sharp, Designing Engineer; and to all others who responded so generously to requests for information, and who contributed to make the examination expeditions, grateful acknowledgment is hereby accorded.

Special recognition is given to the valuable collection of data and studies compiled by the Commission, its engineers, and later by the Department of Conservation and Development, involving research to an extent truly remarkable considering the funds available for the purpose.

SUMMARY.

1. Of over 3,000,000 acres of land embraced within the Columbia Basin, lying between the Columbia and Snake rivers, 1,753,000 are irrigable by the Gravity Project and 1,403,000 by the Pumping Project.

2. The Gravity Project provides water by gravity flow from the Pend Oreille River and its tributaries above Newport, Washington.

3. The Pumping Project provides water from the Columbia River. A pool is formed by a dam, varying from 200 to 285 feet in height, with respective effective heads of 123 to 211 feet, across the gorge of the Columbia at the head of the Grand Coulee, from which water

is pumped by hydro-electric units, each lifting 1,000 second feet approximately 482 feet, or by direct connected units of equal capacity lifting approximately 450 feet, to an artificial lake, whence the water is carried to the land by gravity.

4. The estimated cost for the Gravity Project is \$254,170,351, or \$144.99 per acre. The data on which this estimate is based are much more complete than we have ever found in our experience. The construction is feasible and offers no unusual difficulties.

5. The cost of operation and maintenance for the Gravity Project is estimated at \$841,450, or \$0.48 per acre per annum.

6. The lowest estimated cost for the Pumping Project is \$223,096,943, or \$159.01 per acre. In preparing this cost we have assumed designs of dam, electrical and mechanical equipment, as presented. The difficulties attending the construction are unusual and the pumps proposed have never been built.

7. The cost of operation and maintenance for the Pumping Project is estimated from \$2,610,275 to \$2,192,605 per annum, or from \$1.86 to \$1.51 per acre, depending upon the height of dam adopted.

8. The Gravity Project is recommended for adoption.

9. It is recommended that the entire project be undertaken with a view to completing it in its entirety rather than attempting it piecemeal or adopting temporary construction.

10. The estimated time for completion is six years.

11. The soils of the irrigable lands are fertile and abundant, being in all respects similar to Yakima and Wenatchee valleys; large production will result from water on the lands.

12. A great variety of crops can be produced, and, due to the excellent transportation facilities, can be carried to the markets of the world.

13. No apprehension need be felt about settlement of the lands after water has been placed thereon.

14. All things considered, the project is justified from an economic standpoint if the land can be made ready for planting at a cost ranging from \$200.00 to \$275.00 per acre; at the latter price a profitable return will be secured on the investment.

15. The project, because of the benefits that will accrue to the United States as a whole, is a national one and as such should be carried out by the Federal Government through direct appropriations.

16. Following the existing policy of the Government in its irrigation projects, the farmer or land holder should be taxed to amortize the cost of construction. The Government should bear or absorb the interest charges, which will be more than repaid through the increase that will result to the national wealth, affecting industries and products of all kinds over the entire country.

Very truly yours,

GEORGE W. GOETHALS AND COMPANY, INC.

By (Signed) GEO. W. GOETHALS,
President.

EXHIBIT No. 1.

**REVISED ESTIMATES FOR GRAVITY
PROJECT.**

Exhibit No. 1.

RECAPITULATION OF ITEMS OF MAIN SUPPLY CANAL TO REVISE
TABLE NO. 41, COMMISSION'S REPORT.

ITEMS	Cost	Contin- gencies
1. Dam at Flathead Lake.....	\$475,681	\$30,000
Flathead Lake overflow rights.....	1,587,000	
2. Dam at Pend Oreille Lake.....	649,118	85,000
Pend Oreille Lake overflow rights.....	428,000	
Head Gates.....	859,487	25,000
3. Newport Tunnel.....	15,191,814	1,687,894
4. Canal, Newport Tunnel to Chain Lakes.....	2,211,702	175,000
5. Great Northern Ry change.....	2,812,869	200,000
6. Camden Dam.....	1,296,088	80,000
7. Canal, Camden Dam to Hillcrest.....	18,971,504	1,878,000
8. Dry Creek Dam.....	977,159	40,000
9. Milan Tunnel.....	6,778,677	771,808
10. Deep Creek Tunnel.....	3,070,145	345,085
11. Deep Creek Dam.....	697,494	35,000
12. Road changes at Deadman Creek and Deep Creek Lake	188,000	
13. Deadman Creek Tunnel.....	4,264,818	485,929
14. Deadman Creek Dam.....	3,401,795	160,000
15. Pleasant Prairie Tunnel.....	8,003,698	907,258
16. Spokane River Crossing.....	989,907	50,000
17. S. & I. Ry Crossing.....	29,000	
18. S. & E. Ry Crossing.....	86,950	
19. N. P. Ry Crossing.....	183,155	
20. O. M. & St. Paul Ry Crossing.....	27,340	
21. Appleway Crossing.....	7,218	
22. S. T. Co., Vera Line Crossing.....	20,164	
23. Street Crossings.....	46,837	
24. Manito Tunnel.....	7,150,250	953,871
25. Latah Creek Dam.....	2,110,722	150,000
26. Bonnie Lake Tunnel.....	37,308,897	4,148,781
27. Bonnie Lake Highway Bridge.....	4,818	
28. Rock Lake Dam.....	2,112,492	100,000
29. Wassun Creek Siphon.....	597,200	13,000
30. Emergency Wasteway (Wassun Creek).....	610,315	
31. Dragoon Lake Dam.....	16,059	1,600
32. S., P. & S. Ry Crossing.....	26,901	
33. McCall Dam and Dike.....	331,161	25,000
34. Patterson Tunnel.....	2,000,787	224,958
35. O.-W. R. & N. Ry Crossing.....	101,980	
36. Cow Creek Siphon.....	1,922,671	46,000
37. Hillcrest Siphon and Gates.....	508,949	12,000
38. Drainage Culverts, Albany Falls to Hillcrest.....	9,520	
39. Fences.....	79,296	
40. Telephone Lines.....	91,200	
41. Lateral "MI".....	109,589	23,000
Totals.....	\$127,111,907	\$12,075,761
Grand Total.....		\$139,187,668

Exhibit No. 1—Continued.

RECAPITULATION OF ITEMS OF NORTH DIVISION TO REVISE
TABLE NO. 42, COMMISSION'S REPORT.

ITEMS	Cost	Contingencies
1. Canal, Hillcrest to Ephrata.....	\$14,578,241	\$1,046,100
2. McElroy Tunnel	1,521,638	198,884
3. Paha Tunnel	371,262	44,845
4. Paha Siphon	466,641	9,000
5. Klemmer Tunnel	3,766,480	465,175
6. Branch of Third Coulee Siphon.....	323,437	7,000
7. Second Coulee Siphon.....	1,027,706	20,000
8. Flalg Siphon	434,536	12,000
9. First Coulee Siphon	767,071	10,000
10. Sand Coulee Siphon	773,601	23,000
11. Black Rock Coulee Siphon.....	654,782	14,000
12. Broken Rock Coulee Siphon.....	1,397,980	24,000
13. Round Lake Siphon.....	504,945	8,000
14. Round Lake Flume.....	111,766	1,000
15. Adrian Siphon	2,304,236	42,000
16. Soap Lake Siphon.....	3,123,569	61,000
17. Canals, main from Ephrata to end of line, and all laterals	3,765,810	705,500
18. G. N. Ry Crossing, west of Quincy.....	86,186	.....
19. Potholes Siphon	1,158,319	26,000
20. Frenchman Siphon	668,313	17,000
21. Low Gap Tunnel.....	668,340	33,250
22. Babcock Siphon, lateral "N04".....	309,468	8,000
23. Laterals, Hillcrest to Ephrata.....	1,773,539	72,300
24. Siphon No. 1, lateral "N1".....	10,500	150
25. Siphon No. 2, lateral "N1".....	11,610	100
26. Siphon No. 3, lateral "N1".....	13,645	100
27. Chute, lateral "N2".....	20,397	1,500
28. Flume, lateral "N24".....	23,940	.....
29. Siphon, lateral "N5".....	128,166	2,000
30. Ephrata Siphon, lateral "N6".....	228,839	3,000
31. Chute, lateral "N7".....	16,771	1,000
32. Road Crossings	153,748	.....
33. Fences	256,704	.....
34. Telephones	234,000	.....
Totals.....	\$41,824,197	\$2,831,006
Grand Total.....		\$44,705,301

Exhibit No. 1—Continued.

RECAPITULATION OF ITEMS OF CENTRAL DIVISION TO REVISE
TABLE NO. 43, COMMISSION'S REPORT.

ITEMS	Cost	Contingencies
1. Dam at diversion of Central and South Divisions, costing \$150,908, with a contingency of \$9,300, charged in proportion to relative capacities of canals, 69.6 per cent.....	\$88,430	\$5,000
2. Canal, main line and laterals.....	10,808,116	655,750
3. Tunnel, Providence Main "OC".....	486,472	58,764
4. Tunnel No. 1, Providence Main "OD".....	534,410	64,641
5. Dam, Providence Main "OD".....	41,897	2,000
6. Tunnel No. 2, Providence Main "OD".....	221,387	26,800
7. Siphon, Providence Coulee.....	373,714	7,000
8. Chute, Providence-Shano Main "OE".....	54,960	8,500
9. Chute, Shano Main "OF".....	37,335	2,000
10. Crossing of Connell Northern Ry.....	10,808	.....
11. Drop, Shano Main "OG".....	8,163	.....
12. Siphon, Shano Main "OG".....	841,617	15,000
13. Siphon, Skootenay Springs-Shano Main "OG".....	966,441	20,000
14. Chute, Saddle Mountains Main "OL".....	6,675	400
15. Chute, lateral "O64".....	14,088	500
16. Chute, lateral "O66".....	27,100	1,900
17. Drop No. 1, lateral "O7".....	18,230	.....
18. Drop No. 2, lateral "O7".....	12,140	.....
19. Chute, lateral "O72".....	12,871	750
20. Siphon, lateral "O72".....	53,922	1,000
21. Drop, lateral "O72".....	11,751	.....
22. Chute, lateral "O77".....	18,701	1,250
23. Siphon, lateral "O781".....	186,815	1,000
24. Siphon, lateral "O8".....	189,309	2,000
25. Siphon, lateral "O82".....	39,220	200
26. Chute, lateral "O9".....	25,123	1,750
27. Chute, lateral "O92".....	9,709	650
28. Chute, lateral "OJ1".....	29,798	2,000
29. Road Crossings.....	102,199	.....
30. Fences.....	196,224	.....
31. Telephones.....	175,200	.....
Totals.....	\$15,529,729	\$374,255
Grand Total.....		\$16,408,984

Exhibit No. 1—Continued.

RECAPITULATION OF ITEMS OF SOUTH DIVISION TO REVISE
TABLE NO. 44, COMMISSION'S REPORT.

ITEMS	Cost	Contingencies
1. Dam at diversion of Central and South Divisions, costing \$150,908, with a contingency of \$8,200, charged in proportion to relative capacities of canals, 41.4 per cent.....	\$62,475	\$8,200
2. Canal, South Main and laterals, Hillcrest to end of line	7,820,450	1,098,800
3. South Main, Tunnel.....	911,138	110,607
4. Drop, Snake River, Main "SO".....	12,008	1,300
5. Kahlotus Siphon, Snake River Main "SE".....	2,158,946	30,000
6. Tunnel, Snake River Main "SF".....	359,505	43,370
7. Tunnel, Snake River Main "SG".....	676,420	81,371
8. Siphon, Snake River Main "SH".....	201,061	5,000
9. Tunnel, Snake River Main "SI".....	121,087	14,702
10. Snake River Siphon, Eureka Main "SJ".....	4,036,312	86,500
11. Tunnel No. 1, Eureka Main "SJ".....	109,940	13,369
12. Dam, Eureka Main "SJ".....	46,100	5,000
13. Tunnel No. 2, Eureka Main "SJ".....	577,908	69,792
14. Siphon, lateral "S41".....	201,088	1,300
15. Chute, lateral "S42".....	11,158	700
16. Chute, lateral "S74".....	89,809	3,000
17. Chute, lateral "S81".....	24,465	1,750
18. Chute, lateral "S82" No. 1.....	3,751	150
19. Chute No. 2, lateral "S82".....	26,121	1,450
20. Chute, lateral "S83".....	61,818	4,550
21. Chute, lateral "S84".....	72,905	5,350
22. Siphon, lateral "S85".....	58,820	400
23. Siphon at foot of drop, lateral "S45".....	308,280	5,000
24. Road Crossings	98,799	.....
25. Fences	176,054	.....
26. Telephones	160,200	.....
Totals.....	\$18,725,238	\$1,586,921
Grand Total.....		\$20,311,159

RECAPITULATION OF ALL DIVISIONS TO REVISE TABLE NO. 45,
COMMISSION'S REPORT.

ACCOUNT	Cost	Contingencies	Totals
Supply Canal	\$127,111,907	\$12,075,751	\$139,187,658
North Division	41,824,197	2,381,004	44,205,201
Central Division	15,529,729	874,355	16,404,084
South Division	18,725,238	1,586,921	20,311,159
UNDISTRIBUTED ITEMS—			
Distribution system below 100 second-feet capacity	26,226,000	.....	26,226,000
Spillways and wasteways below Hillcrest.....	1,074,192	89,148	1,163,339
Minor wasteways on distribution system.....	500,000	.....	500,000
Lateral headgates	384,012	19,200	403,212
General incidentals and miscellaneous items, including patrol houses.....	750,000	.....	750,000
General engineering, administration and legal expense, preceding construction.....	1,051,800	.....	1,051,800
Administration, legal and general expense, during construction	2,800,000	.....	2,800,000
Totals.....	\$236,646,077	\$17,524,274	\$254,170,351*

* \$144.99 per acre.

EXHIBIT No. 2.

**ESTIMATED ANNUAL OPERATING COSTS
FOR GRAVITY PROJECT.**

Exhibit No. 2.

ESTIMATED ANNUAL OPERATING COST, GRAVITY SYSTEM.

Flathead Lake Dam—			
1 operator at \$1,500.....	\$1,500		
2 operators at \$1,200.....	2,400		\$3,900
Exit Newport Tunnel, to include Albany			
Falls Dam—			
1 operator at \$1,500.....	1,500		
2 operators at \$1,200.....	2,400		3,900
Camden Dam—			
2 operators at \$1,200.....	2,400		
Dry Creek Dam—			
2 operators at \$1,200.....	2,400		
Deep Creek Dam—			
2 operators at \$1,200.....	2,400		
Deadman Creek Dam—			
2 operators at \$1,200.....	2,400		9,600
Spokane River Aqueduct—			
1 operator at \$1,500.....	\$1,500		
2 operators at \$1,200.....	2,400	\$3,900	
Latah Creek Dam—			
1 operator at \$1,500.....	\$1,500		
2 operators at \$1,200.....	2,400	3,900	
Rock Lake Dam—			
1 operator at \$1,500.....	\$1,500		
2 operators at \$1,200.....	2,400	3,900	11,700
Wassun Siphon—			
2 operators at \$1,200.....	\$2,400		
McCall Dam—			
2 operators at \$1,200.....	2,400		
Cow Creek Siphon—			
2 operators at \$1,200.....	2,400		7,200
Mains below Hillcrest—			
415 miles, one operator per 20 miles, 21			
operators at \$1,200.....			25,200
Laterals—			
1,753,000 acres, one operator per 5,000			
acres, 350 men at \$1,000.....			350,000
Extra gangs—			
1 foreman at \$1,800.....	\$1,800		
5 laborers at \$1,500.....	7,500		
Per gang	\$9,300		
4 gangs at \$9,300.....			37,200
1 general superintendent.....		\$10,000	
4 division superintendents at \$4,000.....		16,000	
4 hydrographers at \$3,000.....		12,000	
4 hydrographer helpers at \$2,400.....		9,600	47,600
Total all personnel.....			\$496,300
Transportation allowance—			
380 cars at \$600.....		\$228,000	
4 trucks at \$1,200.....		4,800	
Annual amount for material and miscellaneous			
supplies		100,000	332,500
Total cost all operating mechanism installed,			
\$317,500, depreciation and upkeep at 2%.....			12,550
Total estimated annual operating ex-			
pense			\$341,450
Annual operating cost per acre, \$0.43.			

EXHIBIT No. 3.

**ESTIMATES FOR PARTIAL DEVELOPMENT
OF GRAVITY PROJECT.**

**(Revised wherever corresponding items in Exhibit No. 1
were revised.)**

Exhibit No. 3.

RECAPITULATION ITEMS FOR PARTIAL DEVELOPMENT, REVISED
AND CORRESPONDING TO TABLE NO. 41, COMMISSION'S REPORT.

ITEMS	Cost	Contin- gencies
2. Dam at Pend Oreille Lake.....	\$649,118	\$35,000
Pend Oreille Lake overflow rights.....	438,000	.....
Head gates	179,244	12,500
3. Newport Tunnel	7,926,172	828,942
4. Canal, Newport Tunnel to Chain Lakes.....	2,211,702	175,000
5. G. N. Ry Change.....	2,312,869	200,000
6. Camden Dam	1,296,089	80,000
7. Canal, Camden Dam to Hillcrest.....	18,971,504	1,878,000
8. Dry Creek Dam.....	977,159	40,000
9. Milan Tunnel	3,070,074	385,684
10. Deep Creek Tunnel.....	1,656,515	178,548
11. Deep Creek Dam.....	667,494	35,000
12. Road changes at Deadman Creek and Deep Creek.....	138,000	.....
13. Deadman Creek Tunnel.....	2,310,611	242,935
14. Deadman Creek Dam.....	2,401,795	160,000
15. Pleasant Prairie Tunnel.....	4,227,529	458,629
16. Spokane River Crossing.....	792,247	30,000
17. S. & I. Ry Crossing.....	29,090	.....
18. S. & I. E. Ry Crossing.....	35,960	.....
19. N. P. Ry Crossing.....	183,155	.....
20. C. M. & St. Paul Ry Crossing.....	27,340	.....
21. Appleway Crossing	7,218	.....
22. S. T. Co.—Vera Line Crossing.....	20,164	.....
23. Street Crossings	46,337	.....
24. Manito Tunnel	3,822,250	476,926
25. Latah Creek Dam.....	2,110,722	150,000
26. Bonnie Lake Tunnel.....	22,086,798	2,074,831
27. Bonnie Lake Highway Bridge.....	4,818	.....
28. Rock Lake Dam.....	2,112,492	100,000
29. Wassun Creek Siphon.....	336,964	6,500
30. Emergency Wasteway (Wassun Creek).....	610,315	.....
31. Dragoon Lake Dam.....	16,069	1,600
32. S. P. & S. Ry Crossing.....	26,901	.....
33. McCall Dam and Dike.....	331,161	25,000
34. Patterson Tunnel	1,075,488	112,488
35. O. W. R. & N. Ry Crossing.....	101,560	.....
36. Cow Creek Siphon.....	1,042,679	23,000
37. Hillcrest Siphon and Gates.....	506,949	12,000
38. Drainage culverts, Albany Falls-Hillcrest.....	9,520	.....
39. Fences	79,236	.....
40. Telephone Lines	91,200	.....
41. Lateral "MI".....	109,589	23,000
Totals	\$36,544,181	\$7,235,178
Grand Total.....	.....	\$98,779,309

Exhibit No. 3—Continued.

RECAPITULATION ITEMS FOR PARTIAL DEVELOPMENT, REVISED
AND CORRESPONDING TO TABLE NO. 42, COMMISSION'S REPORT.

ITEMS	Cost	Contingencies
1. Canal, Hillcrest to Black Rock Coulee, including laterals (Item 23)	\$11,118,218	\$523,080
2. McElroy Tunnel	1,521,688	138,864
3. Paha Tunnel	871,262	44,845
4. Paha Siphon	239,150	4,500
5. Klemmer Tunnel	3,765,480	455,175
6. Branch of Third Coulee Siphon	127,619	2,500
7. Second Coulee Siphon	549,568	10,000
8. Flaig Siphon	254,448	6,000
9. First Coulee Siphon	418,846	5,000
10. Sand Coulee Siphon	451,422	11,500
23. Laterals, Hillcrest to Black Rock Coulee (Included in Item No. 1)		
24. Siphon No. 1, Lateral "N1"	10,500	150
25. Siphon No. 2, Lateral "N1"	11,610	100
26. Siphon No. 3, Lateral "N1"	12,645	100
27. Chute, Lateral "N22"	20,367	1,500
28. Flume, Lateral "N24"	23,990	
32. Road Crossings	89,065	
33. Fences	127,680	
34. Telephones	117,000	
Totals	\$19,325,460	\$1,249,514
Grand Total		\$20,574,774

RECAPITULATION ITEMS FOR PARTIAL DEVELOPMENT, REVISED
AND CORRESPONDING TO TABLE NO. 43, COMMISSION'S REPORT.

ITEMS	Cost	Contingencies
1. Dam at diversion of Central and South Divisions, costing \$150,905, with a contingency of \$3,200, charged in proportion to relative capacities of canals, 58.6 per cent.	\$88,430	\$5,000
2. Canal, main line and laterals	5,236,949	327,500
3. Tunnel, Providence Main "CO"	495,473	58,764
4. Tunnel, No. 1, Providence Main "OD"	534,410	64,641
5. Dam, Providence Main "OD"	41,867	2,000
6. Tunnel, No. 2, Providence Main "OD"	221,387	26,800
7. Siphon, Providence Coulee	228,482	2,500
8. Chute, Providence Shano Main "OE"	54,950	2,500
9. Chute, Shano Main "OF"	37,335	2,000
10. Crossing of Connell Northern Ry.	10,808	
15. Chute, Lateral "O64"	14,098	900
16. Chute, Lateral "O66"	27,100	1,900
17. Drop No. 1, Lateral "O7"	18,230	
18. Drop No. 2, Lateral "O7"	12,140	
19. Chute, Lateral "O72"	12,671	750
20. Siphon, Lateral "O72"	58,922	1,000
21. Drop, Lateral "O72"	11,751	
29. Road Crossings	37,431	
30. Fences	98,112	
31. Telephones	37,600	
Totals	\$7,358,335	\$498,255
Grand Total		\$7,851,640

Exhibit No. 3—Continued.

RECAPITULATION ITEMS FOR PARTIAL DEVELOPMENT, REVISED
AND CORRESPONDING TO TABLE NO. 44, COMMISSION'S REPORT.

ITEMS	Cost	Contingencies
1. Dam at diversion of Central and South Divisions, costing \$150,906, with a contingency of \$8,200, charged in proportion to relative capacities of canals, 41.4 per cent.....	\$62,475	\$8,200
2. Canal, South Main and Laterals.....	4,375,137	540,180
3. South Main Tunnel.....	911,136	110,607
4. Drop, Snake River, Main "SC".....	12,696	1,300
5. Kahlotus Siphon, Snake River, Main "SE".....	1,625,498	15,000
6. Tunnel, Snake River, Main "SE".....	359,505	49,370
7. Tunnel, Snake River, Main "SG".....	676,430	81,371
14. Siphon, Lateral "S41".....	201,698	1,300
15. Chute, Lateral "S42".....	11,158	700
23. Siphon at foot of drop, Lateral "S43".....	205,980	5,000
24. Road Crossings.....	64,784	.....
25. Fences.....	89,032	.....
26. Telephones.....	80,400	.....
Totals	\$9,674,518	\$910,392
Grand Total.....		\$9,485,700

RECAPITULATION ITEMS FOR PARTIAL DEVELOPMENT, REVISED
AND CORRESPONDING TO TABLE NO. 45, COMMISSION'S REPORT.

ACCOUNT	Cost	Contingencies	Totals
Supply Canal	\$96,544,131	\$7,236,179	\$98,779,309
North Division	19,325,460	1,249,314	20,574,774
Central Division	7,353,395	498,255	7,851,640
South Division	8,674,818	510,582	9,485,700
UNDISTRIBUTED ITEMS—			
Distribution system below 100 sec. ft. capacity..	13,200,000	.....	13,200,000
Spillways and wasteways below Hillcrest.....	1,302,881	69,942	1,372,823
Minor wasteways on Distribution System.....	250,000	.....	250,000
Lateral Headgates	192,007	9,600	201,607
General Incidentals and Miscellaneous items including patrol houses	375,000	.....	375,000
General engineering, administration and legal expenses, preceding construction.....	1,051,800	.....	1,051,800
Administration, legal and general expense, during construction	1,500,000	.....	1,500,000
Totals	\$129,769,482	\$9,873,171	\$149,642,653
Acres involved, 880,000; Cost per acre \$170.04.			

EXHIBIT No. 4.

**ESTIMATES FOR COLUMBIA RIVER DAM,
POWER PLANT, AND MACHINERY.**

Columbia River Dam Estimates

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Exhibit No. 4. COST ESTIMATES FOR DAM NO. 1.

DIVERSION OF RIVER—		
Excavation—		
1,120,000 cu. yds. at \$0.60.....	\$672,000	
Concrete, light reinforced—		
20,830 cu. yds. at \$15.00.....	304,800	
Piling—		
28,000 lin. ft. at \$0.60.....	15,600	
Miscellaneous—		
(Lumber, etc.)	2,000	
Total for diversion.....		\$994,400
CONSTRUCTION OF DAM—		
Excavation for dam—		
8,000,825 cu. yds. at \$0.60.....	1,800,195	
8,000,825 cu. yds. at \$1.50.....	4,500,438	
Steel Cofferdams—		
Upstream, 187,000 sq. ft. at \$1.38 (in place).....	249,710	
Downstream, 112,000 sq. ft. at \$1.38 (in place).....	148,960	
Concrete in Dam, 2,199,230 cu. yds. at \$10.50.....	23,091,915	
Concrete in Downstream Apron, 106,500 cu. yds. at \$10.50.....	1,118,250	
Concrete in Diverting Walls, 13,600 cu. yds. at \$10.50.....	143,430	
Engineering	650,000	
Total	\$32,696,248	
Contingencies		\$5,860,000
POWER HOUSE—		
Excavation above draft tube floor.....	523,990 cu. yds. at 60c.....	\$314,329
Excavation below draft tube floor.....	210,000 cu. yds. at \$2.00.....	420,000
Concrete in power station foundation.....	240,000 cu. yds. at \$10.50.....	2,520,000
Light reinforced concrete, superstructure....	79,110 cu. yds. at \$15.00.....	1,186,650
Reinforcing steel	12,494,000 lbs. at 4c.....	497,880
Structural steel	1,823,000 lbs. at 6c.....	109,380
Doors and windows.....		29,200
Painting		59,400
Station wiring		44,170
Traveling cranes		238,800
Backfill for foundation.....	81,500 cu. yds. at 90c.....	73,350
Sump pumps		20,000
Oil pumps and piping for circuit breakers..		4,630
Cofferdam	2,625 lin. ft. at \$1.83.....	340,125
Excavation for forebay.....	568,170 cu. yds. at 60c.....	337,002
Concrete forebay dam.....	368,840 cu. yds. at \$10.50.....	3,872,820
Concrete forebay and wall.....	14,850 cu. yds. at \$10.50.....	155,925
Concrete forebay lining.....	30,490 cu. yds. at \$15.00.....	457,350
Excavation penstocks.....	127,450 cu. yds. at 60c.....	76,470
Steel Penstocks	14,135,000 lbs. at 6c.....	848,100
Concrete penstock anchors.....	1,224 cu. yds. at \$15.00.....	18,360
Engineering		235,000
Total		\$11,867,740
Contingencies		1,736,000
MACHINERY FOR POWER HOUSE—		
Generating station		\$17,659,680
Feeders to pumping station.....		610,160
Miscellaneous accessory machinery.....		418,710
Total.....		\$18,688,550
INTAKES—		
Trash racks	\$210,400	
Head gates and mechanism.....	587,500	
		\$1,047,900

Exhibit No. 4—Continued.
COST ESTIMATES FOR DAM NO. 1.

PUMPING STATION—		
Retaining walls	17,000 sq. ft. steel piling at \$1.33....	\$22,610
Excavation	26,400 cu. yds. at 60c.....	15,840
Concrete, light reinforced.....	18,205 cu. yds. at \$15.00.....	198,075
Reinforcing steel	1,747,000 lbs. at 4c.....	69,880
Excavation, pumping station.....	162,000 cu. yds. at 60c.....	97,200
Cutoff wall steel piling.....	19,500 sq. ft. at \$1.33.....	25,935
Concrete in foundations.....	55,259 cu. yds. at \$10.50.....	580,226
Concrete superstructure	46,317 cu. yds. at \$18.00.....	833,706
Reinforcing steel	5,985,500 lbs. at 4c.....	239,420
Structural steel	183,500 lbs. at 6c.....	11,010
Miscellaneous items		250,430
Engineering		43,000
Total		\$2,177,365
Contingencies		400,000
PUMPING STATION MACHINERY—		
Pumps and motors (17 units of 3 each).....		\$12,316,500
Miscellaneous accessory machinery.....		884,520
Total for machinery.....		\$13,201,020
HOUSES—		
Figuring average force of 180 men, 120		
single family houses at \$3,000.....		
		\$360,000
Three 20 men bunkhouses at \$10,000.....		
		30,000
Total for housing.....		\$390,000
MACHINE SHOP		\$75,000
PIPE LINES FROM PUMP STATION		
TO BEGINNING OF CANAL—		
Hand excavation, earth.....	89,200 cu. yds. at 50c.....	\$44,600
Hand excavation, rock.....	26,000 cu. yds. at \$2.50.....	65,000
Concrete piers	11,700 cu. yds. at \$10.50.....	122,850
Steel pipe	26,049,000 lbs. at 6c.....	1,562,940
Steel standpipes	189,000 lbs. at 6c.....	11,340
Air valves		9,000
Headgates		140,400
Forebay excavation, rock.....	26,830 cu. yds. at \$1.75.....	46,953
Forebay concrete	9,871 cu. yds. at \$10.50.....	103,646
Engineering		42,000
Total		\$2,148,729
Contingencies		330,000

RECAPITULATION ESTIMATES FOR DAM NO. 1.

	Cost	Contingencies	Total
Dam	\$32,696,348	\$5,380,000	\$38,056,348
Power house	11,867,740	1,785,000	13,652,740
Power house machinery.....	18,688,530		18,688,530
Pumping station	2,177,365	400,000	2,577,365
Pumping station machinery.....	13,201,020		13,201,020
Pipe lines from station to canal.....	2,148,729	330,000	2,478,729
Intakes (trash racks and headgates).....	1,047,900		1,047,900
Machine shop	75,000		75,000
Employees houses	390,000		390,000
Total	\$82,292,632	\$7,875,000	\$90,167,632

Exhibit No. 4—Continued.

COST ESTIMATES FOR DAM NO. 2.

Diversion of river (as in Dam No. 1 estimate)		\$994,400
River cofferdams (as in Dam No. 1 estimate) upstream		245,710
River cofferdams (as in Dam No. 1 estimate) downstream		148,980
Excavation 3,318,846 cu. yds. at 60c		1,991,008
Excavation 3,318,846 cu. yds. at \$1.50		4,977,619
Concrete in dam..... 3,842,925 cu. yds. at \$10.50		35,100,718
Concrete in apron..... 106,500 cu. yds. at \$10.50		1,118,250
Concrete in diverting wall..... 15,140 cu. yds. at \$10.50		158,970
Engineering		900,000
Total		\$45,688,530
Contingencies		7,300,000
POWER HOUSE—		
Excavation above floor..... 892,020 cu. yds. at 60c		\$235,572
Excavation below floor..... 205,000 cu. yds. at \$2.00		410,000
Concrete substructure	288,010 cu. yds. at \$10.50	3,024,105
Concrete superstructure	11,452 cu. yds. at \$15.00	171,780
Reinforcing steel	7,098,000 lbs. at 4c	283,920
Structural steel	1,845,000 lbs. at 6c	11,070
Miscellaneous items		870,070
Backfill under floor..... 92,000 cu. yds. at 90c		82,800
Excavation for forebay..... 149,810 cu. yds. at 60c		89,886
Concrete, forebay dam..... 451,320 cu. yds. at \$10.50		4,738,860
Concrete, forebay endwall..... 29,150 cu. yds. at \$10.50		306,575
Concrete, forebay lining..... 24,100 cu. yds. at \$15.00		361,500
Excavation for penstocks..... 223,860 cu. yds. at 60c		134,316
Steel for penstocks..... 14,389,000 lbs. at 6c		863,340
Concrete anchors for penstocks..... 9,468 cu. yds. at \$15.00		142,020
Cofferdam	1,065 lin. ft. at \$133.00	144,305
Trash racks for intakes..... 8,570,000 lbs. at 7c		249,900
Headgates for penstocks.....		741,200
Headgates for discharge pipe outlets.....		140,400
Engineering		250,000
Total		\$12,740,619
Contingencies		2,000,000
PIPE LINES FROM POWER STATION TO BEGINNING OF CANAL—		
Pipe line excavation, earth..... 182,000 cu. yds. at 50c		\$91,000
Pipe line excavation, rock..... 25,000 cu. yds. at \$2.50		62,500
Steel pipe	47,196,000 lbs. at 6c	2,831,760
Steel standpipes	189,000 lbs. at 6c	11,340
Concrete anchors for pipes..... 19,100 cu. yds. at \$10.50		200,550
Concrete lining for pipe tunnel under forebay 5,850 cu. yds. at \$15.00		87,750
Air valves		9,000
Rock excavation for discharge forebay..... 25,830 cu. yds. at \$1.75		45,195
Concrete for discharge forebay..... 9,871 cu. yds. at \$10.50		103,646
Engineering		70,000
Total		\$3,491,998
Contingencies		525,000
POWER PLANT MACHINERY—		
Turbines and pumps.....		\$23,899,900

RECAPITULATION ESTIMATES FOR DAM NO. 2.

	Cost	Contingencies	Total
Dam	\$45,688,530	\$7,300,000	\$52,988,530
Power house	12,740,619	2,000,000	14,740,619
Machinery and accessories.....	23,899,900		23,899,900
Pipe lines from station to canal.....	3,491,998	525,000	4,016,998
Machine shop	75,000		75,000
Employees houses	390,000		390,000
Totals	\$86,236,047	\$9,825,000	\$96,061,047

Exhibit No. 4—Continued.
COST ESTIMATES FOR DAM NO. 3.

Diversion of river (as in Dam No. 1 estimate)		\$944,400
Excavation for dam	3,644,334 cu. yds. at 60c.	2,186,600
	8,500,000 cu. yds. at \$1.50.	5,250,000
Steel cofferdam, upstream	187,000 lin. ft. in place at \$1.33.	248,718
downstream	112,000 lin. ft. in place at \$1.33.	148,960
Concrete in dam	4,803,190 cu. yds. at \$10.50.	45,183,495
Concrete in downstream apron	106,500 cu. yds. at \$10.50.	1,118,250
Concrete in diverting walls	16,180 cu. yds. at \$10.50.	169,890
Engineering		1,110,000
Total		\$56,860,305
Contingencies		8,900,000
POWER HOUSE—		
Excavation above draft tube floor	334,480 cu. yds. at 60c.	\$200,688
Excavation below draft tube floor	143,500 cu. yds. at \$2.00.	287,000
Concrete in power station foundation	154,890 cu. yds. at \$10.50.	1,621,095
Light reinforced concrete superstructure	54,135 cu. yds. at \$15.00.	812,025
Reinforcing steel	8,176,000 lbs. at 4c.	327,040
Structural steel	1,251,000 lbs. at 6c.	75,060
Steel sash and doors		21,000
Painting		42,000
Station wiring		32,720
Traveling cranes		233,800
Backfill for foundation	58,700 cu. yds. at 90c.	52,830
Sump pumps and piping		20,000
Oil pumps and piping for circuit breakers		4,170
Cofferdams	2,100 lin. ft. at \$133.	279,300
Excavation for forebay	147,290 cu. yds. at 60c.	88,374
Concrete in forebay dam	450,900 cu. yds. at \$10.50.	4,734,450
Concrete in forebay endwall	22,500 cu. yds. at \$10.50.	236,250
Concrete in forebay lining	21,710 cu. yds. at \$15.00.	325,650
Excavation for penstocks	192,450 cu. yds. at 60c.	115,470
Steel penstocks	18,020,800 lbs. at 6c.	1,081,248
Concrete anchors for penstocks	6,840 cu. yds. at \$15.00.	102,600
Engineering		220,000
Total		\$10,991,258
Contingencies		1,650,000
MACHINERY FOR POWER HOUSE—		
Generating station		\$10,516,160
Miscellaneous accessory machinery		261,580
Total		\$10,777,690
Feeders to pump station		529,890
Total		\$11,307,070
PUMPING STATION—		
Retaining walls	17,000 sq. ft. steel piling, in place, at \$1.33.	\$22,610
Excavation	26,400 cu. yds. at 60c.	15,840
Concrete, light reinforced	18,205 cu. yds. at \$15.00.	198,075
Reinforcing steel	1,747,000 lbs. at 4c.	69,880
Excavation pumping station	162,000 cu. yds. at 60c.	97,200
Cutoff wall steel piling	19,500 sq. ft. at \$1.33 (in place)	25,935
Concrete in foundations	35,258 cu. yds. at \$10.50.	370,209
Concrete in superstructure	46,317 cu. yds. at \$13.00.	602,121
Reinforcing steel	5,985,500 lbs. at 4c.	239,420
Structural steel	183,500 lbs. at 6c.	11,010
Miscellaneous items		250,430
Engineering		45,000
Total		\$2,177,865
Contingencies		400,000

Exhibit No. 4—Continued.
COST ESTIMATES FOR DAM NO. 3.

PUMPING STATION MACHINERY—		
Pumps and motors (17 units of each).....		\$12,316,500
Miscellaneous accessory machinery.....		884,530
Total for Machinery.....		\$13,201,030
Houses (as in estimate for Dam No. 1).....		\$390,000
PIPE LINE FROM PUMP STATION TO BEGINNING OF CANAL—		
Excavation—earth	89,200 cu. yds. at 50c.....	\$44,600
Excavation—rock	20,000 cu. yds. at \$2.50.....	65,000
Concrete piers	11,700 cu. yds. at \$10.50.....	122,850
Steel pipe	20,049,000 lbs. at 6c.....	1,562,940
Steel standpipe	189,000 lbs. at 6c.....	11,340
Air valves		9,000
Headgates		140,400
Forebay excavation—rock.....	20,830 cu. yds. at \$1.75.....	46,953
Forebay concrete	9,871 cu. yds. at \$10.50.....	103,646
Engineering		42,000
Total		\$3,148,729
Contingencies		890,000

RECAPITULATION ESTIMATES FOR DAM NO. 3.

	Cost	Contingencies	Total
Dam	\$56,880,805	\$8,900,000	\$65,780,805
Power house	10,991,258	1,650,000	12,641,258
Power house machinery	11,807,070		11,807,070
Pumping station	2,177,365	400,000	2,577,365
Pumping station machinery.....	13,201,020		13,201,020
Pipe lines from station to canal.....	2,148,729	890,000	2,478,729
Intakes (trash racks and headgates).....	627,200		627,200
Machine shop	75,000		75,000
Employees houses	890,000		890,000
Totals	\$97,277,947	\$11,280,000	\$108,557,947

EXHIBIT No. 5.

**REVISED ESTIMATES FOR PUMPING PROJ-
ECT BELOW MAIN CANAL INTAKE.**

Exhibit No. 5.

ESTIMATE REVISION OF TABLE NO. 55, COMMISSION'S REPORT.
Main Supply, Exclusive of Columbia River Dam.

ITEM	Amount	Contingencies	Total Amount
Overflow damages above Columbia River Dam...	\$1,000,000	.....	\$1,000,000
Pumping plant (covered in Exhibit 4).....	750,000	.....	750,000
Railroad (thirty miles at \$25,000 per mile).....	4,865,284	\$479,952	4,865,284
Canal, Columbia River Dam to Bacon Lake.....	8,742,098	185,000	8,927,098
Grand Coulee Lake, both dams.....	70,760	5,000	75,760
Grand Coulee, outlet gates.....	4,086,552	496,140	4,582,692
Bacon Tunnel	197,290	10,000	207,290
Bacon Dam	54,100	4,500	58,600
Bacon Dam, outlet gates.....			
Totals.....	\$14,235,084	\$1,170,592	\$15,405,676

ESTIMATE REVISION OF TABLE NO. 56, COMMISSION'S REPORT.

West Main Canal.

ITEM	Amount	Contingencies	Total Amount
Canal, main and all laterals.....	\$7,305,323	\$556,450	\$8,121,773
Quincy main, tunnel No. 1	150,964	18,980	169,944
Quincy main, tunnel No. 2.....	132,852	16,660	149,512
Quincy main, tunnel No. 3.....	241,538	30,290	271,828
Dry Coulee inverted siphon.....	468,250	7,690	475,940
Grand Coulee inverted siphon.....	2,164,173	18,460	2,182,633
Great Northern crossing west of Quincy.....	86,186	.....	86,186
Potholes inverted siphon.....	1,768,790	37,200	1,805,990
Frenchman inverted siphon.....	842,836	19,810	862,646
Low Gap tunnel.....	698,840	88,250	787,090
Inverted siphon on lateral N94.....	309,498	8,000	317,498
Inverted siphon on lateral N6.....	228,339	8,000	236,339
Chute on lateral N7.....	16,771	1,000	17,771
Road crossings	61,827	.....	61,827
Fences	140,650	.....	140,650
Telephone lines	127,200	.....	127,200
Totals.....	\$14,699,087	\$1,100,210	\$15,799,297

Exhibit No. 5—Continued.

ESTIMATE REVISION OF TABLE NO. 57, COMMISSION'S REPORT.

East Main Canal.

ITEM	Amount	Contin- gencies	Total Amount
Canal, main and all laterals.....	\$92,707,186	\$5,817,090	\$98,024,276
Crossing of Washington Central Railway.....	10,572	750	11,322
Long Lake tunnel No. 1.....	576,867	72,220	648,667
Long Lake tunnel No. 2.....	210,469	26,400	236,869
Long Lake tunnel No. 3.....	275,231	34,520	309,751
Stratford tunnel.....	1,385,874	173,810	1,559,684
Orab Creek inverted siphon.....	2,717,633	34,190	2,751,823
Broken Rock inverted siphon.....	2,924,934	57,900	2,982,734
Black Rock inverted siphon.....	1,152,567	24,520	1,177,087
Black Rock tunnel.....	786,947	98,520	884,467
First Coulee inverted siphon.....	2,783,267	51,030	2,834,297
Weber Coulee inverted siphon No. 1.....	2,772,653	50,580	2,823,133
Weber Coulee inverted siphon No. 2.....	2,131,890	39,110	2,170,500
Lind Coulee inverted siphon.....	2,107,549	49,220	2,156,839
Providence tunnel.....	3,233,753	399,330	3,623,083
Ounningham inverted siphon.....	244,469	6,460	250,929
Hatton inverted siphon.....	367,843	8,980	376,776
Rattlesnake inverted siphon.....	201,100	5,680	206,780
Reeder tunnel.....	554,574	69,660	624,234
Washtucna inverted siphon.....	2,343,181	30,950	2,374,131
Delany tunnel No. 1.....	217,240	27,210	244,450
Delany tunnel No. 2.....	206,637	26,230	232,867
Delany tunnel No. 3.....	209,637	26,230	235,867
Delany tunnel No. 4.....	131,772	16,490	148,262
Inverted siphon on lateral N5.....	123,168	2,000	125,168
Crossing on Connell Northern Railway.....	13,910	.....	13,910
Inverted siphon on main "OG".....	841,517	15,000	856,517
Skootenay Springs inverted siphon.....	966,441	20,000	986,441
Inverted siphon on lateral "O72".....	53,922	1,000	54,922
Inverted siphon on lateral "O73".....	169,515	1,000	170,515
Inverted siphon on lateral "O8".....	189,309	2,000	191,309
Inverted siphon on lateral "O82".....	89,220	200	89,420
Inverted siphon on lateral "O84".....	201,688	1,800	203,488
Reinf'd concrete inverted siphon on lateral "O82".....	186,250	5,000	191,250
Snake River inverted siphon.....	4,026,312	86,500	4,112,812
Tunnel, Eureka main SJ No. 1.....	109,940	13,269	123,209
Tunnel, Eureka main SJ No. 2.....	577,908	69,792	647,700
Dam on Eureka main SJ.....	51,100	5,000	56,100
Inverted siphon on lateral S93.....	58,820	400	59,220
Chutes and drops, entire main.....	398,842	23,750	422,592
Road crossings.....	231,417	.....	231,417
Fences.....	403,200	.....	403,200
Telephone lines.....	375,000	.....	375,000
Totals.....	\$99,224,635	\$5,983,231	\$105,107,866

Exhibit No. 5—Continued.

ESTIMATE REVISION OF TABLE NO. 58, COMMISSION'S REPORT.

Recapitulation, Columbia River Pumping Project.

ITEM	Amount	Contingencies	Total Amount
Overflow damages above Columbia river dam.....	\$1,000,000	.....	\$1,000,000
Pumping plant (covered in exhibit 4).....	.....	.....	.....
Railroad to Columbia river damsite, 30 miles at \$25,000 per mile, including salvage.....	750,000	.....	750,000
Canal, Columbia river dam to Grand Coulee lake.....	1,007,210	\$119,952	1,127,162
Grand Coulee lake, overflow rights and dams at each end.....	\$,983,098*	185,000	4,168,098
Grand Coulee lake, outlet gates.....	70,760	5,000	75,760
Canal, Grand Coulee to Bacon lake.....	\$,378,074	360,000	3,738,074
Bacon tunnel.....	4,035,553	436,140	4,521,693
Bacon dam.....	197,230	10,000	207,230
Bacon dam, outlet gates.....	54,100	4,500	58,600
Sub-total, main supply, excluding Columbia river dam.....	\$14,476,094	\$1,170,592	\$15,646,676
East main canal to Snake River and laterals.....	\$63,039,908	\$6,467,340	\$69,507,148
Eureka main canal and laterals.....	6,184,727	415,991	6,600,718
West main canal through Quincy district, and laterals.....	14,689,037	1,100,210	15,789,247
Distribution system below 100 second feet capacity.....	21,045,000	.....	21,045,000
Spillways and wasteways on main canals.....	722,748	49,600	772,348
Spillways and wasteways on laterals.....	400,000	.....	400,000
Lateral headgates.....	463,218	23,161	486,379
General incidentals, miscellaneous items, including patrol houses.....	600,000	.....	600,000
General engineering, administration and legal expense preceding construction.....	841,800	.....	841,800
Administration, legal and general expense during construction.....	2,240,000	.....	2,240,000
Totals (excluding Columbia river dam, power plant, and machinery).....	\$124,702,517	\$9,226,794	\$132,929,311

* Note—Of this amount, \$241,000 is for overflow damages.

ESTIMATE REVISION OF PUMPING PROJECT.

Final Recapitulation of Entire Pumping Project.

	With Dam No. 1	With Dam No. 2	With Dam No. 3
Canal system.....	\$132,929,311	\$132,929,311	\$132,929,311
Dam and pumping.....	90,167,632	96,061,047	108,557,947
Totals.....	\$223,096,943	\$229,990,358	\$241,487,258
Cost per acre.....	\$159.01	\$163.21	\$172.12

EXHIBIT No. 6.

**ESTIMATED ANNUAL OPERATING COSTS
FOR PUMPING PROJECT.**

Exhibit No. 6.

ESTIMATED ANNUAL OPERATING COST FOR DAM NO. 1.

GENERATOR HOUSE—		
39 water wheel tenders—(3 shifts of 13 men each) at \$1,500..	\$58,500	
Oilers—4 groups, 8 men per shift, 36 men at \$1,800.....	64,800	
Switchmen—4 groups, 8 men per shift, 36 men at \$2,100.....	75,600	
2 water wheel tender foremen per shift, 6 men at \$2,700.....	16,200	
1 oiler foreman per shift—8 men at \$2,700.....	8,100	
2 switchmen foremen per shift—6 men at \$2,700.....	16,200	
1 assistant superintendent per shift—8 men at \$7,500.....	22,500	
1 general superintendent.....	20,000	
1 timekeeper per shift—8 men at \$3,400.....	7,200	
1 bookkeeper at \$2,400.....	2,400	
2 office men per shift—6 men at \$2,400.....	14,400	
1 messenger per shift—8 men at \$1,500.....	4,500	
Upset sum for extraordinary conditions during ice season...	25,000	
Headgates, 4 men per shift—12 men at \$1,500.....	18,000	
Total generator house.....		\$353,400
PUMP HOUSE—		
Pump tenders, 17 per shift—51 men at \$1,500.....	\$76,500	
Pump tenders, 2 foremen per shift at \$2,700.....	16,200	
Oil system, 2 men per shift—6 men at \$1,800 (same foremen to handle this work).....	10,800	
Switchboard men, 2 men per shift—6 men at \$2,100.....	12,600	
Total pump house.....		\$116,100
Total power house personnel.....		\$469,500
PORTION OF PROJECT BELOW BEGINNING OF CANAL—		
Grand Coulee outlet gates—		
1 man at \$1,500.....	\$1,500	
2 men at \$1,200.....	2,400	\$3,900
Bacon dam—		
1 man at \$1,500.....	\$1,500	
2 men at \$1,200.....	2,400	\$3,900
Main canals, 216 miles, 1 man per 20 miles—11 men at \$1,200.	13,200	
Laterals, 1,408,000 acres, 5,000 acres per man—281 ditch tenders at \$1,000.....	281,000	
Extra gangs—		
1 foreman at.....	\$1,800	
5 men at.....	1,500	\$9,800
3 gangs at \$9,800.....	27,900	
1 general superintendent.....	10,000	
3 division superintendents at \$4,000.....	12,000	
2 hydrographers at \$3,000.....	6,000	
2 hydrographer helpers at \$2,400.....	4,800	
Total irrigation personnel.....		\$332,700
TRANSPORTATION ALLOWANCE—		
300 cars at \$600.....	\$180,000	
3 trucks at \$1,200.....	3,600	183,600
Total estimated cost of power and pumping plant machinery \$31,939,550—Depreciation at 5% per annum including upkeep.....		1,594,475
Grand total, using Dam No. 1.....		\$2,610,275
Annual cost per acre, \$1.83.		

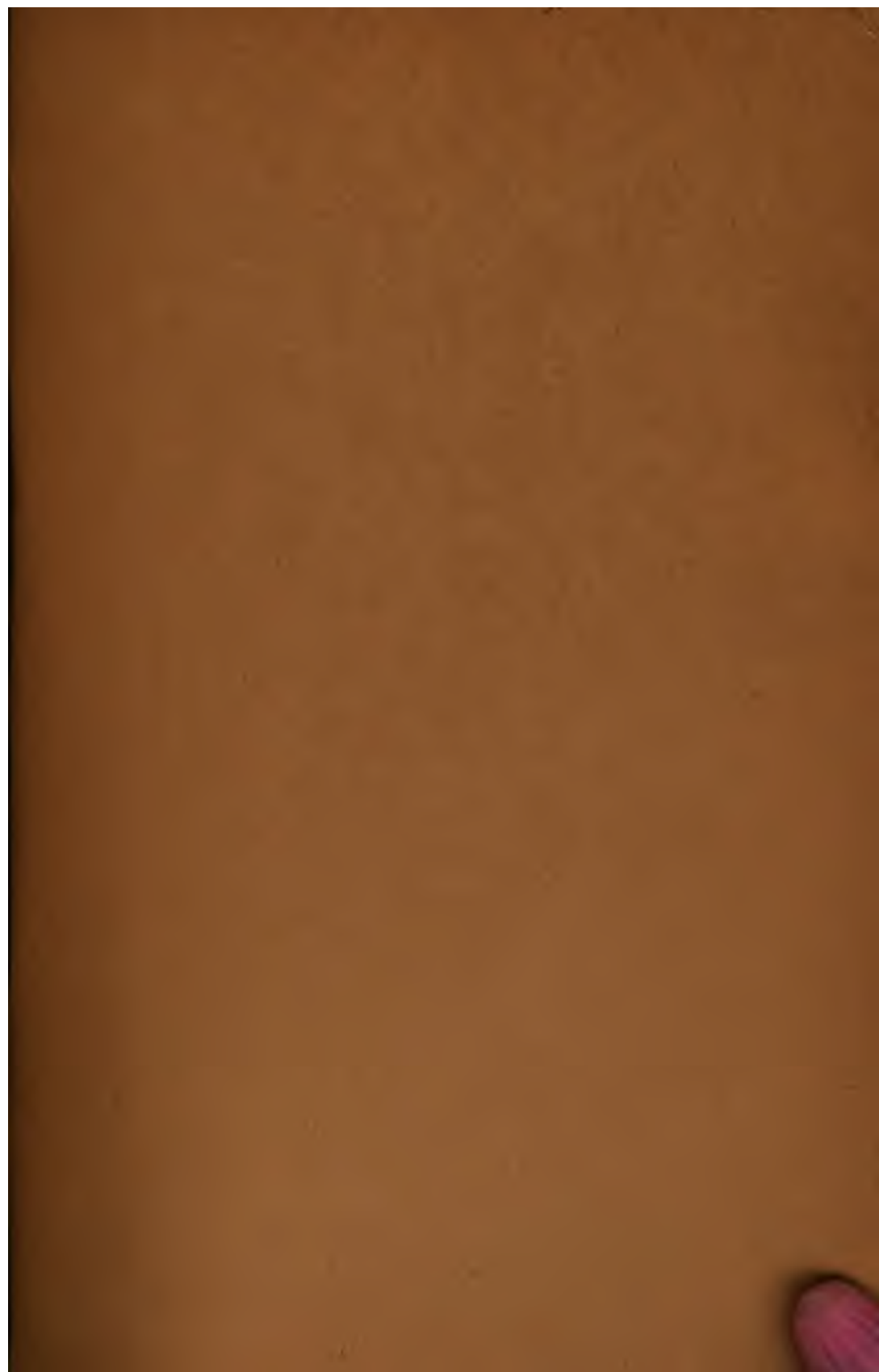
Exhibit No. 6—Continued.

ESTIMATED ANNUAL OPERATING COST FOR DAM NO. 2.

POWER HOUSE—		
Water wheel tenders, 17 men per shift—51 men at \$1,500.....	\$76,500	
Oilers, 17 men per shift—51 men at \$1,800.....	91,800	
Water wheel tender foremen, 2 men per shift—6 men at \$2,700.....	16,200	
Oiler foremen, 1 per shift—3 men at \$2,700.....	8,100	
1 assistant superintendent per shift—3 men at \$7,500.....	22,500	
1 general superintendent at \$20,000.....	20,000	
1 timekeeper at \$2,400.....	2,400	
1 bookkeeper at \$2,400.....	2,400	
1 office man per shift—3 men at \$2,400.....	7,200	
1 messenger per shift—3 men at \$1,500.....	4,500	
Headgate tenders, 3 men per shift—9 men at \$1,500.....	13,500	
Upset sum for extraordinary conditions during ice season...	25,000	
Pump tenders, 17 per shift—51 men at \$1,500.....	76,500	
2 foremen per shift—6 men at \$2,700.....	16,200	
Total power station personnel.....		\$382,800
PORTION OF PROJECT BELOW BEGINNING OF CANAL—		
Total irrigation personnel (same as for Dam No. 1 estimate).....		\$362,700
Transportation allowance (same as for Dam No. 1 estimate).....		188,600
Total estimated cost of power plant machinery, \$23,899,900		
—Depreciation and upkeep at 5%.....		1,194,995
Grand total, using Dam No. 2.....		\$2,124,095
Annual cost per acre, \$1.51.		

ESTIMATED ANNUAL OPERATING COST FOR DAM NO. 3.

GENERATOR HOUSE—		
27 water wheel tenders—3 shifts of 9 men each at \$1,500.....	\$40,500	
Oilers, 3 groups, 3 men per shift—27 men at \$1,800.....	48,600	
Switchmen, 3 groups, 3 men per shift—27 men at \$2,100.....	56,700	
Water wheel tender foremen, 2 per shift—6 men at \$2,700.....	16,200	
Oiler foremen, 1 per shift—3 men at \$2,700.....	8,100	
Switchmen foremen, 2 per shift—6 men at \$2,700.....	16,200	
Assistant superintendents, 1 per shift—3 men at \$7,500.....	22,500	
1 general superintendent at \$20,000.....	20,000	
Timekeepers, 1 per shift—3 men at \$2,400.....	7,200	
1 bookkeeper at \$2,400.....	2,400	
Office men, 2 per shift—6 men at \$2,400.....	14,400	
Messengers, 1 per shift—3 men at \$1,500.....	4,500	
Headgates, 4 men per shift—12 men at \$1,500.....	18,000	
Upset sum for extraordinary conditions during ice season...	25,000	
Total generator house.....		\$300,800
PUMP HOUSE—		
Pump tenders, 18 per shift—54 men at \$1,500.....	\$81,000	
2 foremen per shift—6 men at \$2,700.....	16,200	
Oil system, 2 men per shift—6 men at \$1,800.....	10,800	
Switchboard men, 2 men per shift—6 men at \$2,100.....	12,600	
Total pump house personnel.....		\$120,600
Total power station personnel.....		\$420,900
PORTION OF PROJECT BELOW BEGINNING OF CANAL—		
Total irrigation personnel (same as estimate for Dam No. 1).....		\$362,700
Transportation allowance (same as estimate for Dam No. 1).....		188,600
Total estimated cost of power plant machinery, \$24,508,080		
—Depreciation and upkeep at 5%.....		1,225,405
Grand total, using Dam No. 3.....		\$2,192,605
Annual cost per acre, \$1.56.		





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